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MAN: A CONSTITUTIONAL INVESTIGATION

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1. THE HISTORY OF THOUGHT ON CONSTITUTION

FROM very early written records there is evidence of people believing in some sort of intimate association between the physical make-up of human beings and the various other constituents of their biological patterns.

The Bible and the writings of the Chinese and Hindus indicate that centuries ago men considered that the character of individuals is betrayed by external appearance.

It is not at all surprising, accustomed as one is to the wide range of speculations attributed to him, to find that Aristotle (5) is said to have declared, in his *Physiognomonica:*

> There never was an animal with the form of one kind and the mental character of another: the soul and body appropriate to mankind always go together, and this shows that a specific body always involves a specific mental character.

Writing in Latin, Aurelius Cornelius Celsus (51) (53 B.C. – A.D.) advised:

> Above all things one should know the nature of constitution, why some persons are slender, others fat; some are hot, others more cold; some moist, others more dry; why some have tight bowels, others free. Rare is the person who has not some weak part of the body.

Celsus appears to be the first medical writer to observe that physical constitution may be a factor in the etiology of disease.

Important historically is Galen's (95) theory of Krasis, for from it arose the notion of temperaments, which will be examined further on.

In the third century A.D. the Greek writer Polemonis (237) continued along Aristotle's lines of observations, and a century later Adamantius (1), a Jewish physician, busied himself with similar observations.

So far little has been said specifically of predisposition to disease. But as early as the fifth century B.C. Hippocrates (129) was writing of a habitus phthisicus and a habitus apoplecticus; and saying that those who contracted a certain fever were infants, young persons, adults having smooth bodies, white skins, straight and black hair, and dark eyes.

Avicenna (7) (*circ.* 980–1037 A.D.) makes numerous allusions to the im-

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portance of taking "temperament" into consideration in the study of character and in defining certain functions in an individual. But, like Hippocrates and Galen, he does not particularly correlate form with disease.

Immediately after the Renaissance in Italy there came about a revival of science. At that time the Neapolitan philosopher Giambattista della Porta (66) (1536–1615), influenced by Aristotle, Polemonis, and Adamantius, made correlations between facial characteristics and moral and intellectual traits. This scholar was also somewhat of a caricature artist, and it is interesting to examine his drawings illustrating the parallels between men with certain qualities and the animals regarded as the prototypes of these specific qualities.

Of historical interest to anthropologists is the fact that in 1654 Johannis Sigismundi Elsholzius (77) had established a method of taking measurements of the body and had for the first time employed the word *anthropometria*. It is of further interest to note, in this connection, that Quetelet (239), great Belgian mathematician and astronomer (1796–1874), in 1871 was the first to study measurements of man statistically, using chiefly the figures of artists as the only appreciable source up until that time; and he thought he invented the word *anthropométrie*, unaware apparently that Elsholzius had employed it over two hundred years previously.

One of the first to attempt to correlate constitution with psychiatric disease was Walkington (321). In his *Optick Glasse of Humors* (1663), he expresses his opinions on the relation between function and form as revealed by a physiognomonical analysis.

John Hunter (137) (1728–1793) was unusually scientific in his attitude toward the various aspects of constitution. He believed that the symptoms of a disease were the result of the interaction between certain constitutions and pathologic forces. Within the individual himself, said Hunter, certain systems may show a greater susceptibility to disease than others:

> Thus as the liver in some constitutions is more susceptible to secreting bile, which is its natural action, than it is in others, so also it is more susceptible of its peculiar diseases in some constitutions than it is in others. (p. 304.)

He also said that susceptibility to disease varied with constitutions:

> For example, some constitutions are more susceptible of inflammatory fevers than any other fevers; others are more susceptible to putrid fevers; while either one or the other of these constitutions might have some other disease, either violently or mildly, as smallpox, measles, etc. (p. 303.)

Hunter recognized how complex is the nature of constitution, and how varied were its applications to the study of disease.

One man is especially interesting for his curious conception that since whatever is beautiful and harmonious is holy and good, then all men with good historical reputation had in full the physical characteristics associated with valor, virtue, etc. Lavater (168) was a Swiss—a Protestant minister. His writings were often unintentionally humorous.

At about this time phrenology began to receive serious consideration. Two reputable anatomists, F. J. Gall (96) (1757–1828) and J. C. Spurzheim (283) (1776–1832), fell into the error of believing that mental traits could be read by means of the shape of the head, because various qualities were localized within it. Their work was especially discredited by the adoption of their observational techniques by a rising profusion of phrenological charlatans. Phrenology was but one of

two branches of constitutional somatology to endeavor to connect intellectual capacity, talents, and disposition with morphology.

Criminal anthropology also concerned itself with such related problems. Cesare Lombroso (178), whose name is still revered and respected by many, discovered that in criminals there are to be found certain anatomic "abnormalities" or "stigmata," which are, he said, normally found in lower animals. Therefore, reasoned Lombroso, criminals with these marks are a throwback in the evolutionary scale, and criminality in certain of its forms is an atavistic trait. Though Goring (106) and Perrier (229) exposed certain weaknesses in the argument, the theory has never been entirely discredited. The recent work of Professor Hooton (134) of Harvard, while not in the least subscribing to the Lombrosian doctrine of atavism, was largely inspired by the still-present interest in the subject. (See section V.D. 1.)

Simultaneous with the physiognomic stress given to the study of the body-build was the theory of temperaments. The famous physicians of the Graeco-Roman period left as their chief heritage a fourfold classification of constitutional types. Influenced by Empedocles' and Pythagoras' four primary elements (fire, water, earth and air), they spoke of four "humors"—blood, lymph, black bile and yellow bile—which by their state of balance decided health and disease. The individual's anatomical, physiological, and mental characteristics reflected the dominance of one of the humors, and Hippocrates (129) and Galen (95) and their disciples down through the centuries believed that in order to diagnose and treat disease it was necessary to ascertain the patient's temperament in terms of such humors.

The humoral theory has never been completely discarded, and today persists in altered form, particularly in some of the medical thought on human constitution. In the middle of the nineteenth century Thomas Laycock (169) of the University of Edinburgh used a sevenfold classification not very different from the an cient one.

Jean Esquirol (83) (1772–1840), the French alienist, was influenced by the post-Galenic descriptions of temperaments. He observed that when persons of the lymphatic or phlegmatic temperament fall into mania or monomania they tend to a chronic and deranging course of the disease, whereas those of sanguine, strong and robust temperament tend more to the acute course of the psychosis. Esquirol's classification, though hardly scientific, anticipates in a way the modern distinction between manic-depressive types with a more acute course, and schizophrenic types with more chronic and degenerative courses.

With the opening of the nineteenth century came an awakened interest in many phases of constitution, and the great English clinicians of the time made valuable contributions. Though the foremost student of the problem was Jonathan Hutchinson (138), Feigenbaum and Howat (87) point out that it is wrong to suppose he had faith in the relationship between constitution and diseases, for Hutchinson said the student of constitution

> . . . will discover he is mistaking for criteria of temperament conditions which are simply indicative of youth, or age, or health or disease, or the effects of past anxiety or trouble . . . so should the student of temperament scrupulously reject all that has been superadded and is in a sense accidental. . . . Indeed it may be questioned whether in a large majority of cases there usually exists in persons as yet in perfect health any peculiarity by which we can predicate or discriminate the "fundamental mode of vital activity" (constitution).

The study of constitution was neglected for many years after Pasteur's researches on bacteria and many other bacteriological and pathological advances of the latter half of the nineteenth century had rolled up an immense enthusiasm for the study of the exogenous factors of disease. In Europe, particularly in Germany, Austria, Italy, and France, where the tradition of the endogenous—constitutional—factors lived in many of the older physicians and scientists, the newer interest in exogenous factors never entirely displaced the constitutional approach to biological problems. In the United States, however, with modern medical schools developing only since the time of Pasteur, the absence of the older constitutional tradition has been felt and evidenced in the almost entire absence of a consideration of constitution in medicine. This state of affairs has persisted up until very recent years.

The contemporary phase of constitutional studies may perhaps be attributed to the interest of di Giovanni (68); but to understand his background it is necessary to know that he derived his inspiration from Beneke, a German pathological anatomist, who in 1878 and 1881 expressed a new viewpoint in constitutional studies. For, whereas through the years many had made observations on the exterior of the body, Beneke was the first to measure the internal organs and their variations in size, as associated with age, disease, and body type. However, we must not forget that as far back as 1632 Spigelius (282) had described a ratio between intestinal length and body length; and in 1764 de Haën (65) had tried to relate the variations in position of internal organs to disease. Beneke (26, 27, 28, 29) ascertained two somatic types, the scrofulous-phthisical constitution, which may be compared with the asthenic type in more recent terminology, and a second type, comparable to the more recent pyknic, which Beneke believed to be associated with rachitism in children and cancer in adults.

The concept of type among humans has fallen into serious disrepute in recent years, particularly as the result of biometric analyses which fail to show multimodal distributions of human characters, which can be the only logical basis for clear recognition of types. Among the older authors, like Beneke, just what is meant by "type" is not quite clear, but it seems to refer to an aggregation of individuals around some special criterion, as linearity, robusticity, or solidity. Speaking statistically, it may be permissible to consider a type as one of several individuals at or near an extreme of any biological variation with respect to some especial quality—e.g., beyond 1.5, or 2, or 3 standard deviations from the mean in either direction. Obviously if different criteria or combinations of criteria are used for examining the same population, there may be a large number of types. In this sense, a "type" as an "extreme"—a deviate of statistical significance from the mean—is entirely different and quite distinct from an "average" or "normal," which latter terms connote non-significant deviation from the mean.

Di Giovanni (68) was the only one to take serious notice of Beneke's work, and listed other diseases associated with the two types. He also stated that the cause of the special morbidity of an organ system resides in its disproportionate development relative to other organs. In evaluating di Giovanni's work, we note two important contributions: first, that he observed the apparent changes in habitus and consequently of morbidity that are due to age, and advocated that body growth be constantly observed; and, second, that he was responsible for more exact methods of determining body build, employing for this purpose the techniques of anthropometry. Two other Italians, Viola and Pende, carried on di Giovanni's work and have helped form one of the most important schools of constitutional thought and research existing today.

SUMMARY

Thus we note an extremely early interest in the relationship between the body of man and other characteristics of his constitution, and a gradual evolution, in increasingly sharper focus, of the understanding of these problems. And it would seem that scientific thought of earlier periods has been seriously affected by the extensive advances made in the last 80–90 years in the fields of bacteriology, histology, physiology, biochemistry, and allied branches of biological science.

It is important to recognize that the bulk of this scientific investigation has been directed at a study of the environmental influence affecting man, or of the effect of such environmental factors upon man, rather than at the importantly different matter of the manner in which man's constitution affects and reacts upon environment, in determining his own behavior. One shrewd observer (134, p. 394) has noted, for example, that the medical profession "faced for centuries with the most blatantly obvious structural-functional relations, . . . has . . . turned away and occupied itself exclusively with diseases, microorganisms, pharmacology, hygiene, immunology, and everything except man itself." In short, it seems permissible to state that in the scientific advances of the last century the study of man's constitution has been, if not completely lost sight of, at least thrust temporarily into the background by a much-needed investigation of man's environment as it affects and influences his behavior.

Deeply impressed with the significance of constitutional knowledge, Viola (310, p. 1634) considers the beginning of scientific work in this field to be one of the milestones in medical history, comparing it with the advances inaugurated by the work of Mondino, Harvey, Malpighi, and Pasteur.

It will be well now to consider more thoroughly the exact nature of man's constitution.

II. THE NATURE OF CONSTITUTION

A. Preliminary definition of constitution

For the purposes of introducing a consideration of the nature of constitution, it will be defined as *the total biological make-up of an individual*. Several aspects of constitution and some of the conflicting theories on this subject will be considered. Though the term constitution may obviously cover a vast field, one cannot be immediately concerned with all possible ramifications, such as a detailed consideration of the relationships between body-build and crime, temperament, and intelligence. These will be dealt with briefly in a later section.

B. Constitution a multi-sided problem

It is obvious that the problem of constitution is a multi-sided one. In fact it has so many aspects that many writers have quailed at the prospect of considering it *in toto* and have fractionated it in varying degrees.

Yet it is important constantly to maintain a perspective and to keep in mind the fundamental unity of the biological organism that is man, even when admitting the necessity of dividing the problem as a whole into a number of aspects in order to study it more objectively.

Many authors have considered only comparatively minor aspects of constitution, such as variations in morphology, including relatively small parts of the body, as the ear (Vollmer, 311 and Bean, 21), the scapula (Graves, 109), etc.; or they have limited their observations to the more important, but still incom-

plete, consideration of the relationships of body build to disease, as will be seen later in this paper. Medical writers in particular have been prone to use the word constitution rather loosely, as in speaking of constitutional disposition, constitutional effect, etc. (e.g., Mazer, Meranze, and Israel (194) speak of the "constitutional effects" of large doses of estrogenic principle) without making clear the meaning of this term.

The further tremendous diversity of biological variables that may be considered under the general heading of constitution is well illustrated by the following brief samples of investigations in this field: Strina (296) considers the question of the possible existence of a special somatic type among unmarried mothers; Lorentz (179) discusses indices and a "new constitutional formula" in the study of athletes in the 1936 Olympic games; Amano (4) considers the influence of climate on the human body with special reference to baseball matches; Houghton (135) finds it worth while to consider certain constitutional patterns as hazards of anesthesia; Bartels (12) takes up the question of gymnastics and a dietary regime for pyknics. The profusion of studies on this subject, in its less, as well as its more clearly defined aspects, is best illustrated by the fact that in the last five years of the *Cumulative Quarterly Index Medicus* over 1000 titles are listed under the heading Constitution; and Julius Bauer has from time to time listed the constitutional bibliography with additional hundreds of titles (e.g., 17, 18).

Amid this welter of divergent thought it is necessary to make some division of the field of constitution into logical subdivisions that are at once at least partially discrete, susceptible of correlational study and reasonably conformant to the present state of our knowledge of man. Fortunately there is among the more serious students of this field some considerable agreement as to the form which such a sub-division should take. Even the ancients, as has been seen above, distinguished between form and behavior, psychological or "humoral." Barbára (9) noted that the classifications of the Italian school in a measure restored the four-fold classification of Hippocratic medicine and in modern terms its humoral basis. Pende (228), student of Viola, finds it convenient to employ a "semiological analysis" of constitution according to three "criteria," all springing from an hereditary base—the morphological, the dynamic-humoral (neuro-chemical), and the psychological—to unite, like the faces of a three-sided pyramid, in an apex of the total development and integration of the personality.

Brandt (40), in addition to a consideration of the rôle of heredity in constitution, studies the morphology, the physiology, including growth and differentiation, and the psychology of individuals. Draper considers the study of human constitution to fall naturally into four "panels of personality," in which one may investigate "the hereditary unit characters found in the domains of anatomy, physiology, psychology, and immunity" (69, p. 25). It is not quite clear why Draper separates immunological factors from other physiological characters. Pearl and Ciocco (221, p. 650) in studying human constitution consider the integrated biological relations "between the morphological, physiological, psychological, and pathological characteristics of the individual." Miller (197) uses a trichotomy of morphological, physiological and psychological aspects. This seems to be the commonest mode of dividing the field of constitution into a number of different

aspects. Insofar as pathology (or anomaly) may be considered an "abnormally" extreme deviation of biological characters varying "normally," however, the physiological and pathological aspects of constitution may well be considered as one single phase of the subject, and the total number reduced to three—the morphological, the physio-pathological, and the psychological—agreeing roughly with Pende's divisions. It is, of course, necessary to recognize that such separations are purely arbitrary. It is almost impossible in the final analysis to distinguish morphology from function. Psychological aspects of the personality may only arbitrarily be separated from other physiological properties of the individual's nervous system. And pathology may be an abnormal deviation in any of the three aspects, morphology (anomaly), physiology (disease), or psychology (psychosis or psychoneurosis). Because the major emphasis in pathology still remains in the field of medicine, however, it seems justifiable to allocate this aspect of constitutional variation primarily to the physiological face of Pende's pyramid.

Finally, in a discussion of the aspects of constitution, it is well again to emphasize the essential unitary pattern of the individual. In the study of the relation of constitution and disease in man many authors have emphasized the necessity of treating man as a whole. Typical are the opinions of Rippy (244), Benedetti (23, 24), and Hnat (131). Pearl and Ciocco (221, p. 650) state that the study of constitution has for one of its major objectives a study of the "integrated biological relations" between the various characteristics of the individual. Hooton reflects the same philosophy when he says (132, p. 6), after mentioning physiology and psychology as well as various morphological relationships: "They are merely bound together in an indissoluble organic association, such that one may be predicted, to some extent, from the other." And Draper is a particularly able advocate of the unitary approach to man in a consideration of any aspect of his constitution (72, 73). In his plea for the constitutional approach to an individual as a "complete organism," he uses a meaningful phrase, to denote man a "complete psychosomatic being" (73).

It will be useful, from this perspective, —that of the multi-sided problem of an individual's constitution, springing from an hereditary base, with morphology, physiology, and psychology, all influenced to some extent by environment, as arbitrarily but usefully differentiated aspects of an individual's total personality—to study further some of the concepts of various authors which exhibit conflicting theories as to the nature of constitution, particularly as to the relative rôles of heredity and environment. From an evaluation of these concepts it may be possible more exactly to define constitution.

C. Conflicting theories regarding the nature of constitution

It is not entirely clear if a definition of constitution should include only inherited tendencies, that is, those characteristics present in the germ plasm at the time of conception. The emphasis of the so-called genetic school of constitutionalists has been almost wholly on heredity. Beginning with Martius, one sees that it is the genotype which determines constitution, not environmental influences. According to Martius (190–191), constitution is ". . . the somatic aggregate (inclusive of irritability and liability to disease) that remains the relatively unaltered possession of the individual, with the

characteristic reactivity of the organism more or less permanently fixed." Tandler (298) and Julius Bauer (13, 14, 16) make a similar limitation and keep the term *condition* for the make-up as it exists from the action of external forces. Actually, such a distinction is not easy or even possible.

For this reason most authors have decided that in settling this problem of the determining factors of different diseases, it is necessary to consider the effect of environmental influence. Chaillou and MacAuliffe (52), students of Sigaud, stressed the environmental factor in their four-fold classification of man, believing that the four points at which he had chief contact with his environment—respiratory, digestive, muscular, cerebral—had much to do with the way the soma developed one of these organ systems more predominantly than the others, as a sign of resistance to a particular type of unfavorable environment, including disease. Petersen (230) points out that at least from the medical point of view constitution cannot remain static and the term must embrace not only the quality of the protoplasm in its form and structure, but also the functional status as made apparent in physiological and pathological reactivity; in adaptability to change in environment; in modifications produced by season, climate, diet, age, endogenous and exogenous irritants, disease, physical and mental trauma, and the ever varying forces of the universe of which the individual is a part.

Borchardt (37, 38) does not think it possible to divide constitutional anomalies into hereditary and acquired. He also disagrees with the distinction between constitution and condition, saying the former cannot have a heredo-biological foundation alone. So he defines it as

> . . . the status of the individual as conditioned by heredity and environment; it is the totality of the individual, in structure, form, appearance, physical and psychological ability, reactivity, the condition of the nutrition, the resistance to infections and intoxications, the psychic make-up irrespective of the contingency of the individual phenomena or heredity of environmental influences.

Similarly, Draper (71) says that the term constitution ". . . should connote that aggregate of hereditarial characters, influenced more or less by environment, which determines the individual's reaction, successful or unsuccessful to the stress of environment." He hastens to point out how difficult it is to say which of the so-called inherited values are true germ plasm transmissions, as for example, eye color, and which are habit or imitative characters, such as certain family tricks of gait or gesture. Brugsch (42) says that

> Constitution is the unity of the physico-chemical elements which make up a definite definable system whose coordinating internal forces establish . . . a balance with the external forces whereby the internal forces are laid down in the genes but the final stamp is placed on the constitution by reactivity to environment.

Walter Freeman (92) gives the following definition: "The constitution of an individual may be defined as the sum-total of all his peculiarities and potentialities. Just how much is a matter of genes and how much is conditioned by early environment cannot be determined accurately." (p. 805.) And Feigenbaum and Howat (87) state: "Constitution may be defined as the sum total of native or acquired characters by virtue of which the individual is rendered more or less susceptible to disease. . . ." They point out, in addition, certain practical difficulties in evaluating the constitution: (1) One must be reasonably sure that certain body proportions are not *caused* by the disease. For this reason they avoided selecting diseases which are characterized especially by cachexia, and also chose as measuring points certain skeletal points not likely to be affected by the disease except in

unusual cases. (2) The racial factor is an important one. And (3) discrepancies in results will appear because of statistical differences in selection of material, unless great care is taken to equate such factors.

SUMMARY

From these samples, it would seem to be the consensus of authoritative opinion that constitution in its many-sided aspects is not to be thought of, in its narrowest sense, as strictly or even predominantly a hereditary characteristic of the body, as the hereditary school of constitutionalists would insist, but as expressing the sum total of biological characteristics, both genotypic and phenotypic.

It will be appropriate to examine further in some detail the rôle of heredity in determining the various aspects of constitutional behavior.

D. The inheritance of constitutional factors

The nature of gene dominance and recessiveness in man is not clearly determined, and our knowledge varies with various details of the constitution.

1. The inheritance of morphological characters

Morphological characteristics, such as eye color and hair color, are more readily studied with their relation to heredity than physiological and other constitutional characteristics. If heredity were the sole determinant of type, then the problem of racial classification would be solved, but while it is accepted that genetic factors operate in determining the constitutional aspects of the body, it is known that the genes concerned are so numerous and environmental factors so important, that inheritance of racial type can be spoken of only in a broad sense. It is more profitable to deal with the hereditary basis of bodily proportions of one individual as compared with another, for with few exceptions, which are the result of selective processes, there are no bodily forms typical of any race.

Most of the work in the inheritance of physical traits in man has been done by anthropologists. Their method has been to utilize racial hybridization. The results of such studies are very informative, for there seems to be no reason why their findings may not be applied to inheritance *within* racial groupings. Krogman (161) has gathered data on the heritability of non-pathological traits in man, the groups studied by the several investigators whose material he utilizes being mostly White-Indian, White-Negro, and White-Asiatic. He says:

> In general man is subservient to genetic rules. Physical traits tend to act as unit characters. In a cross there may occur a phenotypic blend, but genotypic modifications occur rarely as mutations. . . . The environment plays a definite rôle. The genetic constitution does not change, but its expression may vary, the optimum may or may not be achieved.

Krogman divides features into three categories, depending on their value for analysis of race or group physical traits.

It is obvious that in assessing heritability of constitutional types such definite principles of analysis cannot be followed, for though there is undoubtedly a racial factor to be considered in establishing types many of the features of physique are non-racial. It is possible, however, to utilize the anthropologists' knowledge of physical inheritance.

Study of the Dionne quintuplets has afforded interesting data regarding the inheritance of behavior, personality, and temperament. Blatz (33) says that despite the fact that all five carry exactly the same types of whatever genes there are for behavior, personality and temperament, the girls show even greater variations in these characters than in physical make-up and mentality. This would seem to indicate that environment must be

considered as a constantly operating factor. Newman's (213) study of identical twins causes him to conclude that they show marked similarities in behavior and personality which cannot be entirely explained on the ground of similar environment; that physical characters are affected least by environment; intelligence more; education and achievement still more; and personality and temperament most.

Ritala (245), using a different approach, has studied the inheritance of body measurements in new-born children, and has found some definite correlations.

Thus even in a consideration of man's body, his most fixed character, it will be seen that it is difficult if not impossible to distinguish between strictly hereditary and strictly environmental factors. That even the factor of nutrition as it affects morphology may not be primarily an environmental one is suggested by Montessori (203, pp. 75–76), who finds that the broad, lateral, or stocky individual has a larger volume of digestive organs as related to his total body mass than does the slender, linear individual. She suggests that this may be an hereditary factor influencing physical status in addition to the strictly environmental one of the amount of food ingested. Montessori has characterized the linear individual as having a small boiler and a relatively large engine, and the lateral individual as having a large boiler with a smaller engine! However, objective facts are not completely available as yet to support this thesis, and Draper (71) finds this part of the morphological problem much more complex than Montessori's presentation would indicate. Studies relating internal organs to external dimensions have also been contributed by Bean (20), Castaldi (50), Rössle and Roulet (250), students of Castaldi, and by Pearl, Gooch, and Freeman (222), among others.

It is apparent that human morphology or body-build is probably in large part fixed by heredity and to some small extent influenced by environmental factors. Davenport (63), in a study of inheritance in body build, believes that the stronger of these two elements influencing morphology is one of pure gene heredity. He seems convinced that he has been able to prove satisfactorily that such morphological characters as height and body build in general are the expression of two or three, or in a few instances as many as four, determiners of heredity; and that there may even be more hereditary determiners influencing morphology through the indirect means of physiological variation; and that environmental factors play a relatively minor rôle in the determination of human morphology.

An extremely important consideration in this connection is the constancy of the body build. This will be discussed in some detail in a later section, under the discussion of age as a factor in constitution (see section II. E. 3.).

2. The inheritance of physiological characters

If there was difficulty in establishing the influence of heredity as distinguished from environment in the determination of morphological characters, it is obvious that the problem is infinitely more complex in the case of the study of inheritance of physiological characters. Little enough is known of inheritance in man anyway. Petersen (230) in commenting on this problem says: "The human is a poor animal for genetic study; the interval between generations is too long, the control of the characteristics bred utterly impossible." The closest approximation

in man to the laboratory methods of observation of the operation of hereditary factors in animals is in the study of physiological processes in identical twins, and it is fortunate that a number of careful studies have been made in this field, not only with regard to physiological processes but also with respect to disease propensities (see section II. D. 4.).

In Germany, for example, Lenz (172), Siemens (276), von Verschuer (318, 319), and Weitz (325) studied respiratory rhythm, blood pressure responses, and characteristic pulse frequencies, and felt that they found sufficient evidence to establish the strong likelihood of the heritability of these characters. Curtius (60) and Curtius and Korkhaus (61) in identical twins found marked similarities in response to such physiological tests as injections of epinephrine and the Volhard test (the determination of urine secretion and of the hemoglobin after taking a certain amount of water on an empty stomach), the latter test in many cases exhibiting an absolute concordance in the two twins. Geyer (101) in general confirms these observations. Curtius and Korkhaus (61) in one pair of identical twins even found identical extra systoles, suggesting that perhaps identical stimuli affected the vagi as well as the heart ganglia in an identical manner in the two individuals, thus indicating the probable hereditary influence of such physiologic regulation. They likewise observed other similarities in physiological phenomena, as similar or identical pigment distribution and vascularization of the skin.

K. H. Bauer (19) in cross-grafting skin from one identical twin to the other noted the "humoral identity" of the skin of such twins. According to Petersen (230), Westergreen studied the sedimentation rate in unioval twins and found marked parallelisms. On the other hand, Bernheim-Karrer (30) studied the bactericidal property of the serum of identical twins and found decided differences, so it is clear that not all physiological properties of identical twins are necessarily similar.

Another interesting approach to this problem of the inheritance of physiological characters has been made by E. Fischer (90) who studied Boer-Hottentot bastard crossings and noted many apparently significant differences in the behavior of the resultant filial generations.

In the field of physiology the inheritance of blood group types is one of the clearest demonstrations of Mendelian gene inheritance. Within recent years the genetics of new and independent antigens has been satisfactorily determined. In 1910 von Dungern and Hirschfeld (313) held A and B to be dominant, and O recessive. Bernstein (31) showed in 1924 that there are six genotypes and four phenotypes, and this number was increased to ten and six respectively when a "strong" and a "weak" A were found by Thomsen, Friedenreich, and Worsaae (300).

An important advance occurred two years later when Landsteiner and Levine (167) postulated two new and independent antigens, M and N, resulting in two systems, ABO, and MN, which give eighteen classes of blood. Each of the six ABO blood groups is divided into three classes according to the presence of M, N, or MN.

The matter has been further complicated by Friedenreich's (94) demonstration of an N_2, recessive to the ordinary N gene (now N_1), and an A_3, dominant to O (as are A_1 and A_2) but recessive to A_1 and A_2. The complete ABO system now has fifteen genotypes and eight phenotypes.

Though the evidence is far from conclusive, there is good reason to believe that heredity determines physiological be-

havior as well as morphology, to a very large extent, even though environment may play an appreciable rôle.

3. The inheritance of psychological characters

It is harder to speak with assurance regarding the inheritance of psychological types and patterns. There is a growing belief that they are to a large extent predetermined by heredity, though environment surely plays a relatively large part. Nathaniel Hirsch (130), on the basis of a study of over one hundred similar and dissimilar twins, concludes that though both heredity and environment contribute to the development of intelligence in humans, their contributions are far from being equal, heredity being about five times as significant as environment in determining I.Q. differences between twins.

According to the studies of Seashore (264–268), the various senses required for musical aptitude have a constitutional basis. A genetic study of musical talent by Scheinfeld (259) causes him to conclude that "musical talent is in all probability inherited through a number of genes acting together, and without the required genes there can be no musical talent" (p. 271). But he does not dismiss or neglect the influence of environment, which he believes cannot create talent but may suppress or "veto" it.

Summing up the prevalent beliefs of psychologists regarding the various factors involved in producing personality, Scheinfeld (259, pp. 298, 299) says that the likelihoods of their being produced by heredity are:

Most likely to be influenced by heredity: Basic abilities, such as intelligence, speed of reaction, motor skills, sensory discrimination, etc.

Less likely to be influenced by heredity: Temperamental traits, such as emotionality, alternation or evenness of mood, activity or lethargy, and other characteristics in which gland activity is conceivably involved.

Least likely to be influenced by heredity:——(if at all)—Attitudes, stylistic traits, beliefs, values, and other such characteristics in which training or conditioning are clearly major factors.

4. Heredity in relation to the etiology of disease

Of more interest perhaps to many is the question similar to those asked of the rôle of heredity in morphology, physiology, and psychology: what is the relative importance of heredity in the predisposition to disease?

All disease may be defined as simply an "abnormal" or "pathological" variation of biological processes ordinarily varying "normally," in an individual or in a group of individuals. A recognizable disease entity obviously is not a simple biological matter, and is the result of variations in a number of related biological processes. Yet there is scarcely a biological picture to be recognized as pathological—i.e. a disease—which does not have at sub-clinical levels its closely approximated counterpart, different only in degree of abnormality—i.e. deviation from the mean behavior. This is true in practically every field of biological pathology, whether morphological, physiological, or psychological. In the field of medicine many examples could be given; here it is necessary to mention only one: the work of Konjetzny in the field of carcinoma of the stomach. Konjetzny (153, 154), studying chronic hypertrophic gastritis as a possible precancerous condition, finds in some stomachs situations where it is quite impossible to define the borderline between a benign and a malignant condition, and concludes that the entity malignancy, under such circumstances, is unquestionably a relative matter. The same may even be said of many

infectious diseases, as tuberculosis, pneumonia, influenza; of degenerative diseases, as of the cardio-vascular-renal system; and even of traumatic accidents and other acute surgical conditions: in essentially any kind of pathological variation, there is an ill-defined zone between normality and abnormality, between health and disease.

If this concept of disease be tentatively accepted, the basic problem can then be stated: What is the rôle of the hereditary aspect of constitution in the occurrence of these extreme degrees of biological variation—i.e. in the etiology of disease; and the allied problem, how can a consideration of these matters aid in a better understanding of the nature of constitution? In the constitutional consideration of pathology and disease there are many aspects subservient to the rôle of heredity's contribution to the etiology of disease. Some of these will be discussed in a later section (see section V. C.). Here will be considered briefly the rôle of heredity in predisposition to disease.

The same difficulties encountered in studying the relationship between heredity and physiology naturally are evident here. But enough valid observations have been made to permit Borchardt (37) to list a considerable number of pathological conditions as they seem, according to various workers, to have definite hereditary constitutional factors in their etiology, dependent on dominant, recessive, or sex-linked recessive hereditary characters.

In various diseases heredity naturally plays a varying rôle. Hemophilia perhaps is the best illustration in man of a disease with a sex-linked inheritance. Otosclerosis seems proven to be dependent on a strong endogenous (hereditary) factor. Häcker (118, 119) believes that, on the basis of the family history, diseases may be grouped in one of two categories: (a) "associated with Mendelian transmission," or (b) an "inherited . . . constitution or a certain habitus or status—a soil on which varying pathological conditions may develop, depending on conditions."

In addition to such diseases as those in which the hereditary element plays a proportionately large or even determining rôle, there are many diseases which are relatively impartial in their selection of victims. These in man are chiefly the infectious diseases, where the environmental factors—encounters with bacteria—are largely determinant. There are other pathological conditions in which disease seems to be due more largely to such fortuitous, not innate, determinants as nutrition, poisons, irritants, physical accidents, psychic influences, and the loss of acquired immunity. But even in the face of such circumstances it is necessary to remember that individuals vary widely in the form and severity of their reaction to their exposure to approximately equal amounts of such non-hereditary forces. Thus it is suggested that even in such conditions the hereditary constitutional element is at least partly a determinant of the course of the disease. Further discussion of the relation between constitution in general and disease will be deferred to a later section.

In between the extremes of pathological conditions determined predominantly by heredity or by environment, and ignoring those diseases in which the etiology is unknown, must be recognized a third and intermediate class, for it is not possible to place many pathological conditions at or near either of these extremes. In this middle group are to be found those diseases in which the determinants are largely but not wholly both endogenous and exogenous: diseases of the glands of

internal secretion and of the autonomic nervous system, both sympathetic and parasympathetic.

It will be well here to recall that health or disease is essentially the result of a state of balance or imbalance among a great number of biological variables, both hereditary and environmental; morphological, physiological, psychological; all also expressed as a function in time, or of the age of the individual. Pearl (220) has defined this difficult picture well, while discussing the relationship between constitution and health:

> The biological constitution (total personality) of an individual at a given moment depends directly and immediately upon and is determined by, at least, A—The present functional condition (tonus and balance) and state of activity of the endocrine system, the autonomic nervous system, the vascular and vasomotor system, and the central nervous system (psychic influence). All of which in turn depend in part upon B, the physical chemistry of the blood, and the innate degree of perfection (biological worth) of the anatomical structure in general, and of each particular organ, and the age of the individual.

He summarizes by saying that all of these biologically integrated variables derive from "the inherited kind and quality of the biological organization and from the environmental circumstances and forces, past and present." These two factors are usually called the *genotype*,—a term used by Johannsen (142) as referring to the "inherited germ plasm," also called "idiotype" by Siemens (276)—and the *paratype*. In this country geneticists employ the term *phenotype* to denote the individual resulting from the reactions between the genotype (the purely germinal make-up) and the environment (287). Naegeli (209, 210) has made a very thorough study of the genotypic factor in the heredity of many medical entities, and lists a number of interesting genetic mutations.

A useful approach to the study of the rôle of the genotypic factor in disease, as was the case with the relationship of heredity to physiological processes, is to observe disease reactions in identical twins, although even this closest approximation in humans to laboratory conditions leaves much to be desired, and has not been very extensively employed. Siemens (276) cites examples of striking similarities of pathological reactivity in identical twins. Ganther and Rominger (97) have found similar manifestations of exudative diathesis in unioval pairs of twins. Petersen and Levinson (231) studied a pair of such twins infected with tuberculosis, and found that both had been infected in early childhood, that activation of the disease commenced in both between the eighteenth and nineteenth years, and that the clinical findings and courses were identical. And Curtius and Korkhaus (61) found a marked parallelism in the clinical phenomena of tuberculosis in a pair of identical twins, including similar localization of fibrosis, similar tuberculin reactions, and other parallelisms in the lungs and lymph glands. But other observers have not observed similar concordance of tuberculosis in identical twins, so this evidence is not conclusive.

Much work has been done in studying heredity with regard to cancer, both in experimental animals and in man. Loeb (177) and Slye (278) are among those well known for their work in this field. Petersen (230, p. 305), commenting on the problem of heredity in cancer, says: "We presumably deal with two factors, a disposition to blastoma formation on one hand and inheritable resistance on the other. But exogenous elements frequently enter into the initiation of the process." While much is known of the rôle of heredity in cancer in animals, where it is possible to control gene factors to some

extent through careful breeding, it is dangerous to draw close parallels in applying such knowledge to humans. Little (174) in a recent publication states in this connection: "Life superimposes so many varying circumstances and facts that any hereditary tendency so far detected may easily become swamped by other influences. . . . The risk of having cancer because one or both parents had it is not of practical importance."

Perhaps no single infectious disease has been studied quite so extensively in man, with regard to hereditary as well as other constitutional aspects, as pulmonary tuberculosis. This is not to say that conclusive evidence is available to support one hypothesis or another on this subject. Pearson (227) introduced the correlational statistical technique as early as 1912 in an effort to obtain direct evidence as to the rôle of inheritance in a tuberculous diathesis, and believed that the results he obtained were positive, though others have been doubtful. Drolet (76) in 1924 and 1925 maintained that children of tuberculous parents do not inherit a disposition to tuberculous disease but instead exhibit an increasing degree of immunity against it. Gottstein (107) has also made a statistical study of the influence of heredity in tuberculosis. Grimes (113) in an exceedingly interesting study of *The Natural History of Phthisis* in rural Iowa families in 1931 found a *factor besides infection*, presumably identified as heredity, which played the major rôle in the disposition to the disease, though he recognized the importance of immunity, both natural and acquired. Alons (3) and Münter (205) by painstaking studies of tuberculosis in families have tended to support the hereditary hypothesis.

From the experimental biological standpoint comes some interesting further evidence in favor of a considerable hereditary factor in the predisposition to tuberculosis. Lewis and Wright (173) state:

> Using guinea-pigs belonging to families subjected to continuous inbreeding until they are homozygous in the hereditary sense, and subsequent crosses between these strains, it has been definitely shown that resistance to tuberculosis depends in part on factors which are hereditary. The essential independence of these factors of other factors governing color, fertility, and general vigor is indicated. Resistance to experimental tuberculosis in guinea-pigs is much more under the influence of these inherited but undetermined factors than it is under that of certain other factors also concerned, such as sex, age, weight, etc.

Pearl (218) has made a careful statistical evaluation of the relative effects of heredity and environment in the development of clinical pulmonary tuberculosis in man. He was successful in employing biometric techniques to distinguish between the relative importance of contact (environment) in families in which tuberculosis existed, and heredity *and* contact—by studying members of households not members of families but in as intimate contact—and thus indirectly was able to distinguish between genotypic and phenotypic factors. He concludes that the hereditary factor is the more important one.

Petersen (230, pp. 304–305), in reviewing much of this evidence for and against the influence of heredity in tuberculosis, says: "Constitution, both genotypic and paratypic, may therefore even be the determining factor in an infectious disease such as tuberculosis."

These considerations as to the rôle of heredity in tuberculosis, to a certain extent typical of similar considerations in all disease, lead to the conclusion that pathology, or disease, in all cases to some degree and in some cases to a high degree, is influenced by heredity as a predetermining factor; and that in this sense an individual when conceived is, within

limits probably statistically definable, likely not only to be of a certain form and shape and to behave in a certain physiological and psychological manner, but also will be likely to deviate from a "normal" behavior pattern in a predictably "abnormal" or "pathological" pattern.

E. Other factors in the determination of constitution

Thus far, in considering the nature of constitution, we have recognized the multi-sided aspect of the problem, involving at least morphology, physiology and psychology, and have included a brief introduction to the concept of resistance to disease. We have further recognized the rôle, in a different dimension, of the factors of heredity and environment. And we have sought to emphasize the essential unity of the constitutional picture. It is clear, however, that these factors already mentioned do not complete the list of variables involved in a consideration of constitution. Closely allied with the hereditary aspects of the problem are the further (partially dependent) variables of race and sex. A further variable to be considered is the variable in time—age. A brief consideration of each of these will enable us more completely to define constitution, and will serve more adequately to introduce the methodology of the study of constitution and a résumé of some of the more important findings made by various workers in the various aspects of the constitutional problem.

1. The race factor in constitution

Is racial distribution a causal factor for the morphological types which have been established by the constitutionalists? Hooton (132, pp. 476–481) says that in his opinion " 'constitutional' types have little racial significance; they are individual types or at most family types." Nevertheless his data show that there are morphological characteristics in races which vary somewhat as do constitutional characters.

Under the "lateral" type he lists several Mongoloid peoples, the Eskimo of the Northwest Coast, the American Indians of the Pueblo district of the Southwest and of Mexico and Central America and most of South America, and most of the Siberian tribes, the European Lapps, and the Alpine race. The "linear" type of man Hooton believes is best exemplified by the Nilotic Negroes, the Turkana, the Suk, the Nandi, the Hamitic Negroids, the Oceanic Negroes, the Australians, the Nordics, some Mongoloids, and American Indians. The type intermediate between these two is not characteristic of any great division of mankind, although it is almost universal among the Polynesians and is predominant in the Mediterranean race.

Hooton does not believe it is possible to relate strongly contrasted types of body build with adaptations for different kinds of diet, for the distribution of human types is not in accord with the dietetic habits to which they are supposed to have been adapted. The tall, slender, long-legged type is called sometimes the "carnivorous" type, yet the Eskimo, who live almost entirely upon animal food, are short, stumpy, and broad; the Pima, Yuma, and many other maize-eating tribes of the Southwest are tall and slender. He believes it is more plausible to relate body build to the endocrine secretions.

Not very much is known about racial physiology. Work with blood groups has yielded tantalizing but somewhat inconclusive information (280). The trouble with most of this work is that it has been done in terms of nationality,

not race. Some of the most widely different peoples are quite alike in percentages of agglutinogens, which leads to the conclusion that in our present state of knowledge blood groupings are to be regarded as being inherited independently of the physical features of race.

Still less is known of racial differences in pulse, temperature, and respiration frequencies. The few studies made in this field give promise of the existence of significant variations.

Klineberg (151) subjects the work done on the racial factor in physiology to a cautious review, and decides that while it is unquestionable that actual group differences in physiological activity do exist, nevertheless it cannot yet be said that these originate in hereditary factors; in fact, the data even hint at the possibility of some other explanation.

More data have been accumulated regarding the racial factor in disease. Aside from high susceptibility to a few of the contagious diseases brought to the New World to which they have not had time to develop a certain degree of immunity, Hrdlička (136) finds that the Southwest Indians are comparatively free from anemia, affections of the breast, of the circulatory system, asthma, liver disorders, cancer, rickets, hernia, idiocy, and insanity. Even where these Indians show a higher incidence than whites in affections of the gastro-intestinal tract, of the respiratory organs, of the eyes, muscular rheumatism and senile arthritis, small-pox, measles, etc., he believes the condition may not be due to constitutional factors but to climatic, hygienic, and dietetic conditions.

The Negroes in the registered areas of the United States, according to Pearl (219), show less disposition to develop carcinoma than do whites, as well as diseases of the nervous system, the endocrines, and the skin. But of lower incidence in whites are diseases affecting the respiratory system, the female genitalia, and the skeletal and muscular systems.

The enormous survey conducted by Love and Davenport (180) on 2,500,000 war recruits gives abundant data on racial differences in disease. In general, it appears that Nordics show little tuberculosis and venereal disease, defects and disease of the eye, ear, nose and throat, and developmental defects; they are more susceptible to nervous and psychopathic disorders, functional and organic heart disease, and varicose veins. Alpine groups are even less liable to tuberculosis and venereal disease, and have fewer nervous diseases and less mental deficiency; they are more prone to defects and diseases of eyes, ears, nose and throat, heart disease, and developmental defects. The groups with a good deal of Indian admixture are very superior in their resistance to disease in general, except for being greatly susceptible to tuberculosis and venereal disease.

Tuberculosis is a disease which has been studied extensively with regard to its racial predisposition. Statistics are numerous which seem to indicate that not only is the incidence of the disease higher in Negroes than in whites, but that anatomical and pathological characters of the disease differ racially. Typical of such conclusions are those of Everett (84), who in a study of 75 cases found the "childhood type" of tuberculosis more common in Negroes and the "adult type" more common in whites. Johnson and Myers (143), in a study of tuberculosis in infants and primitive races (Indians of Minnesota, Negroes, and Mexicans), find that these racial groups have approximately the same first-infection kind of reaction to tuberculosis as do whites, but that reinfection tuberculosis is likely

to follow a different course in primitives, —thus doing much to clear up the thinking in this field in recognizing first-infection and reinfection forms of tuberculosis as "almost two distinct diseases." F. J. Halford (120), in a study of school children of Hawaiian blood in the Hawaiian Islands, found among these natives a higher incidence of tuberculous infection, a higher mortality from tuberculosis, and certain other differences in the course of the disease, as compared with other racial groups in the Islands; and found further that racial admixtures exerted a definite influence upon these differences. Bogen (35), in a study of racial and national origins of patients admitted to a sanatorium in California, found that definite differences existed in mortality figures, but felt on examining the figures and circumstances that environmental factors more than accounted for the racial mortality differences.

Stern-Piper (290), Pfuhl (234), Ritterhaus (246) and Henckel (126) believe that Kretschmer's constitutional types are really racial in character and that they are not of chance occurrence within races, as Kretschmer claimed. They assert that the pyknic-cycloid type is actually the Alpine race and that the leptosome-schizothymic type is the Nordic. That a racial factor is involved is denied by von Rohden (316), Wertheimer and Hesketh (327), Weidenreich (323), E. Miller (198) and others. Miller's argument is that there are no indications of a predominance of manic-depressive psychoses in races which are rather pyknic in physique, nor of schizophrenia in races in which the majority of people have athletic-leptosome physique.

In his recently published work on criminal types, Hooton (134, p. 104) very explicitly states that while constitutional types are associated with the type of criminal offense, he has carefully considered the racial factor and decided that this is only partly responsible for the types.

Not enough work has been done on classification of body build according to race to be certain of facts in this area. But it seems likely from the preliminary observations of a number of individuals that real and statistically significant differences as to body proportions as well as other morphological characteristics do exist between different races.

2. The sex factor in constitution

The sex factor in man's constitution is of clinical importance. Nature produces not only imperfectly sexually differentiated individuals, but also gives to every individual subtle analogies of form and psychic pattern which endow that individual with a certain gynandromorphism.

Draper (71, pp. 135–137) has listed the frequency of disease with relation to sex. In general, it seems that in the case of men it is the mechanism for energy expenditure which is involved; in the case of women, the diseases involve protective and energy accumulating mechanisms.

Inquiring into the cause of differential sex predisposition to certain diseases, Draper ingeniously reasons thus: There is a definite quality of sex to be found in all of the cells of the soma and the expressions of this are the secondary sex characters. The tissue cells of a male react differently from the tissue cells of a female. Therefore these cellular differences are to be regarded as being just as definitely secondary sex characters as are hair distribution, body contour, and psychic pattern. "From the point of view that sex appears as a fundamental quality of somatic tissue protoplasm, it is clear that the susceptibility of certain

diseases must often behave like a secondary sex character." (p. 142.)

Sex thus is an important factor in the study of the morphological and physiological and pathological aspects of constitution. It likewise plays an important rôle in the psychological aspect of constitution, but here the environmental problem has a proportionately greater influence.

Sex, then, is seen to be a constitutional variable in another dimension than those already considered, although undoubtedly it is to some degree correlated with some of them. In all studies of the rôle of sex in constitution it probably is well to study males and females separately, though it is likewise important to keep in mind the rôle of gynandromorphism, as suggested by Draper.

3. Age and growth and the permanence of the constitutional make-up

The factors of age and growth must be considered both as to their influence on constitutional type and their contribution to the understanding of the rôle of constitution in longevity.

Do morphological characters remain unchanged in the face of increasing age and growth? It was the contention of Sigaud (277) and of Viola (308, 309) that the types of habitus which they had delineated were not altered by age, though Sigaud came to give up this belief, which has been contradicted by the work of Zweig (334), J. Bauer (15), and Brugsch (42). According to Brugsch, the narrow-chested type develops to a normal-chested type in one third of all cases between the ages of twenty-five and thirty-five; and the normal-chested type can change with age to a wide-chested type. Mills (199), who lists major morphological types and sub-types, observes that while type may change from one to another, the change is always from one *sub-type* to another. He studied one thousand persons and found there was no progression from one major class to another.

One major deterrent to the accurate recognition of human morphological types is the undeniable fact that the human body changes size and shape with age, and in addition to doing so under a variety of normal conditions does so under the influence of certain pathological conditions, as the cachexia of advanced cancer or tuberculosis, the adipose changes of pituitary disease, even the skeletal changes of rickets, acromegaly, etc.

To the student of the major changes of the human body for the years of life primarily involved in growth and differentiation, a vast literature is available, among the most reliable studies and summarizations of which seem to have been those of Bardeen, Scammon, and Calkins (10, 256, 257). Several investigators have made serious efforts to classify infants and children according to morphological criteria. Lederer (171) in 1923 found it possible to apply Sigaud's classification quite successfully. Schultz (262) in 1926 was able to distinguish significant individual morphological characteristics even in fetal life. Bakwin and Bakwin (8) made a very thorough study of morphological classification in the early years of life. Ossipowa (214) indicates from her investigations that Kretschmer's morphology and characterology begin early in childhood and that types can be recognized in both dimensions at this stage of development.

Aside from the proportional changes of growth and differentiation, which admittedly make difficult the problem of classifying human morphology in the younger age groups, there are the problems of wide "normal" fluctuations in nutritional status and the less common though

no less real variations in general "condition" or "tonus," especially of the musculature. In other words, it is a matter of every-day observation that individuals may vary considerably with respect to (a) deposits of fat, (b) degree of development of musculature, and even (c) of the more stable skeletal parts of the body, such as degrees of mineralization and osteoporosis of the bones, with age. These fluctuations may well be summed up in the not too specific term "physical status," which may be used primarily to denote degree of fat deposit and muscular development.

The question rightly raised is: Do "normal" changes in physical status, associated with age or other factors, alter the fundamental constitutional picture of an individual? In the sense that there is a marked psychological lability in an individual as the result of many environmental factors, it does unquestionably change. Under certain conditions not only the psychological, but also the physiological and even the morphological pattern of an individual may vary, but such changes may not be said to be "normal." If the question is then rephrased: Do "normal" changes in physical status, associated with age or other factors, alter the fundamental *morphological* constitutional picture of an individual? the problem is more immediately susceptible of accurate evaluation.

Other authors than those mentioned believe that the morphological aspect of constitution does change with age and nutritional status. Wertheimer and Hesketh (327), for example, state that in older individuals there are more pyknics than in younger persons. They quote Möllenhoff (201) as believing the same. Certain it is that if measurements and indices are used as the major determinants of classification of body build, the constitutional picture will change, in that there will be shifting of indices of body proportions. For example, some investigators say that it is not until the twenty-ninth year that the maximum growth and final proportions of the thorax are fixed. For this reason it would seem proper that different values be given to indices with change from one age group to another. This does not mean that there has been a change from one type of habitus to another but that any habitus undergoes indicial modification with the passage of years. Change in morphological indices with age is especially noticeable if weight is one factor in such an index. Wertheimer and Hesketh (327) point out the important changes in weight in later life, especially associated with certain of the psychoses. Draper states (69, p. 98) "the weight character is obviously not entirely a constitutional factor, but depends upon the momentary state of nutrition," implying that weight is in part a constitutional matter, and is in part affected by the physical status.

Many have been the authors who have examined this matter of nutritional status. Most have sought to evaluate this simply with some "nutritional index," depending largely on some mathematical relationship between weight and some linear measurement, usually stature. Other measurements, as sitting height or chest circumference, have been employed in such indices in an attempt to find a more significant relationship, by Fleischner (91), Guttmann (116), von Pirquet (315), Wagner (320), and many others. Basically, however, a height-weight relationship called a "ponderal index" has been the method of attack on this problem. Among the investigators who have approached this problem of an adequate expression of nutritional status with various nutritional and ponderal indices have been Bardeen (10), Dreyfuss (75),

Emmerson (78), Manny (186), Gerber (100), Livi (175), Matusiewiez (192), Rohrer (247), and Brugsch (42). Among the expressions for the ponderal index that have been used are $\frac{\text{Weight}^{1/3}}{\text{Height}}$; $\frac{\text{Weight}}{\text{Height}^3}$; $\frac{\text{Weight}}{\text{Height}^{2.5}}$; $\frac{\text{Weight}}{\text{Height}^2}$; $\frac{\text{Weight}}{\text{Height}}$; and their inverses. Kelly (147) in a careful investigation of this problem found the most satisfactory exact index to be $\frac{\text{Weight}}{\text{Height}^{3.042}}$ for males and $\frac{\text{Weight}}{\text{Height}^{2.79}}$ for females, but that $\frac{\text{Weight}}{\text{Height}^3}$ differed very slightly from these and was adequate for all practical purposes. McCloy and associates (195, p. 105) have adopted $\frac{\text{Weight}^{1/3}}{\text{Height}}$ as the ponderal index of choice, after a very careful consideration of the entire subject. Sheldon (275) has adopted the inverse of this index.

Numerous as have been these efforts to define nutritional status mathematically, they have not succeeded in allowing for the important matter of the relation of the ponderal index to individual variation in body build. One of the best approaches to this vital problem has been that of McCloy and associates (195, 196) at the Iowa Child Welfare Research Station. They take four measurements on the subcutaneous fat (chest front, chest back, supra-iliac, and abdominal) to correct certain transverse trunk measurements; and certain limb (muscular girth and joint diameter) measurements for determining relative musculo-skeletal development; and then by means of suitable formulae and tables are able to give mathematical expression to the individual's relative body build, and so predict the "normal weight" for that particular constitution at that particular age. This technique is a distinct advance in the somametric analysis of body build, for it enables one to use anthropometric data, including the highly labile one of weight, without indicial distortion.

A particularly able study of the effect of exercise upon the musculature has been made by Arnold (6), in a group of athletes, who, theoretically at least, have the greatest potential lability of this particular part of the soma. Arnold finds that, with exercise, the following changes in body measurements occur: the ponderal index decreases due to loss of fat; shoulder breadth, chest circumference, and the thoracic index increase; other breadth measurements of the trunk, and circumferential measurements of the extremities do not change; in the same age group athletes are generally larger and more robust than a random sample of the population; and leptosomes and pyknics decrease and the athletic type increases in frequency.

It will be clear from this discussion, however, that although bodily indices and proportions may change with exercise, nutrition, etc., it does not necessarily follow that the fundamental kind of morphological make-up (constitution) also changes, for indices are not altogether adequate measurements of the body build. It seems likely that if some such technique as that worked out by McCloy and associates had been applied to Arnold's data, radically different conclusions might have been the result.

As the physiological and psychological make-up are less determined by heredity and more influenced by environment, it is evident that they are less constant and permanent with the passage of time, this being the case more with the psychological aspect than the physiological.

An important contribution to the problem of changes in physical build with

age, as related to the development of disease, has been made by Reed and Love (243a), who followed up the incidence of disease in U. S. Army officers ten to twenty years after their admission to the service, when careful anthropometric measurements had been taken. They found, for example, that individuals who developed tuberculosis had a characteristic body-build, judged chiefly according to a height-weight relationship, as much as twenty years before the appearance of the clinical manifestations of the disease (see section V. C. 4.). The officers aged 21–25 who developed tuberculosis twenty years later had a mean weight of 138.39 lbs., with a stature average of 70 in., as compared with averages of 151.27 lbs. and approximately the same height in the entire group—a difference of 12.88 lbs. And the officers aged 26–35 who developed tuberculosis ten years later weighed 142.95 lbs. on the average, as compared with men of the same height averaging 158.21 lbs. in the general group, a difference of 15.26 lbs. In brief, in every age group those individuals who ultimately were to develop clinical tuberculosis characteristically were of a tall spare build as compared with other officers. This kind of study would seem to go a long way toward meeting the criticisms of many observers of constitutional studies, who suggest that a certain body build found to be associated with a given disease is perhaps the result of that disease rather than a predisposing factor in its development.

Another interesting and fruitful source of inquiry has been suggested by Graves (111) in studying the relation of constitution to longevity. The result of three decades of work with scapular types has convinced him that if certain features of the habitus, not subject to age changes, are found in higher percentages among older individuals, then it follows that there is some sort of connection between these features and longevity.

Graves' work is worth describing. He noted that the vertebral borders of scapulae were either concave, straight or convex. After long study, he concluded that these variations in contour expressed capacity for adaptation and survival. His studies of individuals, families, and groups led him to state that the concave and straight scapulae are most frequently found in those who are innately remote from the biological ideal in total make-up and adaptation—the weak, the unhealthy, the "plus-potentially unhealthy." Conversely, convex types of scapulae he found occurred most frequently in those who are strong and healthy. Graves claims that the incidence of the convex type increases from 35 per cent to 65 per cent in the successive age periods from birth to old age, and that this must not be construed to mean that scapular type changes, for after the type is once formed there is no change. Graves explains this age incidence as "better adaptability, less morbidity, less mortality and greater longevity among the bearers of the convex than among the bearers of the scaphoid types."

Up until recently, the only investigations of inherited character-types in relation to age and longevity were those on scapulae. Graves (110) has now inspired other workers to make similar studies of other inherited character-types, such as blood groups. Preliminary results, based on too small a sample, indicate that O is most associated with longevity and AB least.

Pearl and Pearl (224) have stated that longevity may be "regarded as a simple numerical expression of the integrated effects of all the forces that operate on the individual, innate and environmental." They believe that though longevity is

undoubtedly affected by all sorts of environmental circumstances, it is nevertheless intimately connected with the biological constitution of the individual. They have shown by a study of nonagenarians and centenarians that "for every year of superior longevity realized by the longevous group, there is a corresponding superiority in the longevity of their immediate ancestors."

Rössle (249) has likewise studied the constitutional factors involved in living to old age, and concludes that longevity is distinctly an inheritable factor, probably associated with definite constitutional patterns. Few if any careful studies, however, have been carried out to determine the morphological classification of the same individual or group of individuals over a period of time.

In order to ascertain the stability of constitutional make-up it would be best to carry on observations on individuals from birth to death. Unfortunately this has never been done, although Graves (109), on the basis of examinations on two hundred individuals for a period of only eighteen years, believes he has established the fact that the shape of the vertebral border of the scapula is determined by the tenth fetal week and does not change with age. Another part of the constitution which is believed not to change throughout life is the individual blood group (see section II. D. 2.).

Treadgold (304) has observed that it is rare for underweight individuals to change to overweight, and vice versa, as determined relative to common weight standards, and it is an every-day observation that while normal weight may change considerably it rarely changes radically from an under- to an over-weight group.

The problem of the possible change of the morphological constitution is an exceedingly complex and difficult one. Frequently a young man or a young woman in the teens is seen to blossom in later life into the full bloom of a pyknic. This apparent metamorphosis has been sympathetically referred to by Sheldon as a "pyknic practical joke." Any attempt to classify such an individual in early adulthood or earlier solely by strictly anthropometric techniques will not take into account the more elastic structures of the body that are so important in morphological classification. Attempting to measure the soft parts may also lead to error, through faulty techniques or through faulty selection of measurements. It seems likely, at the present stage of constitutional classification, that scopometric classification (see section IV. A. 2. c.) is the most valid, avoiding at once the Scylla of too great subjectivity and the Charybdis of sole reliance on objective measurements; and that, making suitable and adequate allowance for minor changes in physical status, the morphological component-picture, or type, does not change appreciably if at all from birth to death, except under the duress of pathological conditions.

F. Final definition of constitution

Having now considered the nature of constitution from a number of points of view, it will be possible to formulate a meaningful definition of just what constitution is.

Constitution, then, is to be defined as *the sum total of the morphological, physiological, and psychological characters of an individual, with additional variables of race, sex, and age, all in large part determined by heredity but influenced in varying degrees by environmental factors, all of which, when integrated and expressed as a single biological entity, fluctuate in varying degrees over a wide range of "normality" and occasionally cross*

an arbitrary boundary into "abnormality" or pathology.

III. THE UTILITY OF CONSTITUTIONAL KNOWLEDGE

Having examined and defined the nature of constitution, one may well inquire, what is to be gained from a study of constitution?

The main theoretical objectives have been expressed by Pearl and Ciocco (221, p. 30) as follows:

> The study of human constitution has for one of its major objectives the discovery of stable organic correlations (integrated biological relations) between the morphological, physiological, psychological, and pathological characteristics of the individual, and eventually the precise numerical measurements of such correlations. In particular, with regard to the relation between somatic constitution and disease, it seeks the degree of consilience between variation in morphology and normal or pathologic physiology; and the part this plays in predisposition and different individual reactions to infectious and other diseases.

Our ultimate interest in these problems is to take advantage of discoveries thus made and the leads which they provide in diagnosis, therapy, prognosis, and prevention. When this branch of science shall have been established on a strong, scientific basis it should be possible, for instance, to study carefully the individual make-up and recognize those variations which may dispose to certain diseases. Draper (71, p. 239) has likened the defenses of the human being to "the famous British square which Fuzzy-Wuzzy broke," whose four sides are seldom equally strong.

Being aware of the assaults of the environment which continually harass the individual constitution, it should be possible to decide where is the Achilles' heel—the *locus minoris resistentiae*—of the individual, and to endeavor to avoid events, objects and personalities which are apt to provoke in him reactions especially dangerous to the phenotype. Those organic invaders, ways of living, and climatic conditions likely to be most harmful can be avoided, once forewarned.

To aid in understanding those morphological aspects of constitution which are correlated with survival value, Graves (111) has advanced the "age-incidence" principle as a method of qualitative evaluation of the biological significance of the permanent, or relatively permanent, types of inherited characters, whether of structure, function, measurements, or indices. While sound in its logic, Graves' principle has thus far yielded few positive results, primarily because not many research workers have utilized the method.

In addition to contributing possible preventive methods, constitutional knowledge may contribute to actual therapeutic measures. Psychoanalysts have emphasized what good practitioners have known for centuries—that phantasy, imagery and symbolism are important causes of disease. They have been able in many cases to restore disturbed emotional relationships and eliminate disease. Regulation of nutrition, body chemistry, and even internal secretions might be attempted after more is known of their rôle in and influence upon constitution.

In the field of medicine known etiological agents, even in infectious diseases, probably are only partly the explanation of an individual's susceptibility to a given disease. If it were possible to measure and correlate the amount of an infectious agent (size and virulence of dose) against the degree of clinical pathology associated therewith, the correlation would not be perfect. In different diseases perfect correlation would be approximated to a greater or lesser degree. In childhood, for example, exposure to measles is highly correlated with the development of rubeola; the correlation of the develop-

ment of the paralytic form of poliomyelitis with exposure to the filtrable virus of infantile paralysis is lower. To interpret such a statistical expression would mean, in the first instance, that exposure to measles was nearly all the circumstance required to get the disease in childhood; in the latter, that other factors, not represented in the particular bivariate correlational study, are involved to a greater degree. By suitable statistical devices other possible correlates may be discovered, and their combined correlation, expressed in a suitable statistical manner, may be considerably higher than with the single correlation of the disease occurrence with exposure. It seems likely that in this way constitutional factors can be delineated and measured which will add to the total knowledge and predictability of disease.

The aim in modern medicine is to make a doctor, in the first place, a more accurate diagnostician. With further accurate studies in the field of constitution it should be possible to equip the physician with yet another tool in his armamentarium, this time not another laboratory test, but clinical insight into the restrictions of constitutional variation as manifested in disease.

In this connection Coerper (57) summarizes the utility of constitutional knowledge well when he makes a plea for constitutional clinical training as a part of medical training. He points out that to know a disease is one thing, to understand a sick man another; and that methods of constitutional investigation, particularly since the introduction of biometric analysis, are reliable and contribute to the accuracy of diagnosis, prognosis, and therapy, as well as prevention.

Prediction and direction of an individual's biological evolution, however, is a somewhat restricted conception of the possible utility of constitutional investigation. Diagnosis, therapy, and prevention may be considered the chiefly defensive function of man's biological knowledge. Of potentially greater significance is the possibility that, through all scientific knowledge, constitutional and otherwise, man may be so able to control and direct his destinies that true biological evolution will ensue.

(To be concluded)

REGENERATION IN PROTOZOA: A PROBLEM OF MORPHOGENESIS

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I. INTRODUCTION

STUDIES on the problem of regeneration clearly illustrate the dominant trends that have guided the development of protozoölogy. Real contributions to the general subject of regeneration date from Trembley's inaugural work on *Hydra* (1740), following which many other Metazoa were studied. The first intimation of the existence of comparable phenomena in Protozoa was contained in the casual observations of eighteenth century taxonomists and natural historians. In the following century, when the classical studies of Dujardin, Schultze and others had shifted emphasis in protozoölogy to the nature of protoplasm, further incidental records were added. With the discovery of nuclear activity during sexual processes (Balbiani, 1861; Bütschli, 1876; etc.), many came to support the view that the nucleus was the most important constituent of the protozoan cell.

In the late nineteenth century, therefore, the time was ripe to probe the relative rôles of nucleus and cytoplasm in various life processes; regeneration experiments on unicellular organisms afforded a direct method. Unicellular material is desirable in several ways for studies of regeneration. It is possible to separate nuclear and cytoplasmic elements, to remove minute and yet essential constituents, and to correlate nuclear and cytoplasmic activity during the ensuing regeneration. The course of morphogenesis might be expected to proceed more directly in organisms in which the relation of cause and effect is not masked by multicellularity.

The problem of regeneration has been approached in two general ways. Many investigators have been occupied simply with tracing the regenerative capacity of Protozoa. Often guided by little more than intrinsic curiosity, these descriptive studies have not attacked the basic problem. A more fundamental appoach has emphasized the mechanism controlling the regenerative process. The explanation of new-formation of structures has been sought by some investigators in terms of cytoplasmic movements accompanying regeneration; by others, in terms of nuclear activity stimulating the production of formative substances. A few workers have adduced evidence of the activity of physiological gradients during normal and experimental differentiation of Protozoa.

In connection with these studies, it has been found that the regenerative process often simulates the reorganization which accompanies the various phases of a protozoan life history (fission, encystment, and sexual reproduction). In each instance, whether it be a mutilated or otherwise physiologically altered individual, there occurs an initial loss of structural differentiation. Following this process of "simplification" the species-pattern is re-differentiated in all cases by a

fundamentally similar method. This suggests the possibility that one basic mechanism may control both normal and experimental reorganization. If this proves true, then regeneration phenomena too would properly be considered to involve a kind of developmental change.

These various approaches have contributed many data bearing on regeneration. The scope of the present review is to treat the respective groups of Protozoa in the general order of their derivation, and wherever possible to emphasize underlying similarities linking the processes accompanying regeneration and ontogeny. It may be hoped that in this way certain conclusions of general importance will emerge concerning the problems of protozoan organization. Moreover, some of the recent studies on micro-organisms seem to have applicability to more general problems of regeneration. (Discussion of literature bearing on protozoan regeneration may be found also in reports by Bütschli (1887–1889), Przibram (1909, 1929), Sokoloff (1924), and Korschelt (1927).)

II. EARLY ACCOUNTS OF REGENERATION

The older microscopists bore visual witness to the viability of mutilated Protozoa, although in general no effort was made to follow restorative processes. As early as 1769 Ellis had observed the fragmentation of certain ciliates under unfavorable conditions; the surviving pieces continued indefinitely to live and to move. Eichhorn (1783) was stimulated by Trembley's work to test the regenerative response of the large heliozoan, *Actinosphaerium*. In three instances he observed the reconstitution of mutilated individuals. The Italian naturalist, Guanzati (1796), accurately described some interesting form-changes in a hypotrichous ciliate ("*Proteus*"), during which an extrusion of part of the body was followed by restoration of the normal shape.

In the nineteenth century pertinent data appeared in various sources. Ehrenberg's treatise (1838) contained many references to fragmentation in Protozoa by partial cytolysis. Most of these were misinterpreted as illustrating extrusion of eggs and embryos, which was in conformity with the exaggerated complexity ascribed by Ehrenberg to protozoan structure. In fact, the generic characteristics of *Stentor* included the habit of bearing young by cytolysis (p. 262); similar interpretations were made for *Paramecium*, *Stylonychia*, etc. Accidental fragmentation was also recognized, in *S. mytilus*, for example, "Cytolysis produces remarkably active, viable fragments. . . ." (p. 371). No definite indications of regeneration were given in any part of the work.

At about the same time Dujardin (1838, 1841) incorporated his intensive observations into a series of works. In sharp contrast to Ehrenberg, he denied the existence in Protozoa of definite internal organs; to substantiate his view he pointed out that small pieces of experimentally mutilated *S. pustulata* and *Oxytricha pellionella* continued to live, which would not be expected if the missing parts were highly organized (1838, p. 313; 1841, p. 423). Concerning regeneration Dujardin made the happy surmise for ciliates that, ". . . if, despite their small size, one could cut them into fragments, each part would continue to live and would become a complete infusorian again . . ." (1841, p. 31).

Perty (1852) supported Dujardin's views but did not refer to regeneration. Claparède and Lachmann (1858–1861), on the other hand, opposed these views. They summarized their position by stat-

ing, ". . . we are not yet convinced that a fragment of any kind from these animals [the ciliates] can reproduce a complete individual." (p. 11).

Stein's monograph (1859) contained scattered references to the survival of fragments of ciliates (*S. mytilus*, p. 151; etc.). He reached the same conclusion as some of the above workers, that many supposed genera of early investigators like O. F. Müller were actually pieces of well-known species. The large hypotrich, *Urostyla*, was observed to recover its normal form and activity following experimental mutilation (pp. 193, 195).

Max Schultze's study of protoplasm (1863) led him to investigate the effect on viability of crushing foraminiferan shells. The miliolid species he used remained active for a short time, but he did not record any regeneration. In Haeckel's collected biological studies (1870) appear references to cutting experiments on *Actinosphaerium*, *Myxastrum* and *Protomyxa* (p. 22, 34). Fragments behaved normally during the brief period of his observations.

Some contributions of little importance include Wreśniowski's observation (1870) that *Stylonychia pustulata* mutilated by predatory *Dileptus* apparently continued to live; Parker's reference (1883) to an alleged "reproduction by partial dissociation" following natural fragmentation of *Amphileptus fasciola*; Worcester's similar account for *Stentor coeruleus* (1884); and Gruber's record for *Oxytricha* sp. (1885a).

III. ORGANIZED STUDIES OF REGENERATION

The previously cited works threw little light on the problem of regeneration beyond indicating a rich, unexplored field. Meanwhile the first organized studies were being made, and since 1880 an ever increasing series of investigations has probed the extent of protozoan regeneration.

(1). *Mastigophora*

Turning to the groups of Protozoa in the general order of their derivation, we find in the first instance few experiments involving flagellates. Peculiarly enough, the types used have been highly specialized. Kofoid (1908) described regeneration following autotomy in *Ceratium*, an armored dinoflagellate. Depending upon environmental fluctuations, its long horn-like extensions could be lost and replaced by new ones. Huber-Pestalozzi (1922) experimentally induced the breaking of the horns of *Ceratium hirundinella* by centrifugalization. In the subsequently regenerated structures he described a relatively high incidence of malformations ("hyperplastic regeneration").

Noctiluca miliaris is a fragile, luminescent form which is also included within the Dinoflagellida. Webb (1855) definitely noted regeneration in mutilated individuals and thereby satisfactorily disposed of Busch's interpretation (1851), and the later observation by Pouchet (1885), that these represented reproductive stages. Some years later Dönitz (1868) and Cienkowski (1873) described the restorative process in *Noctiluca*. Following injury and the resulting collapse of the turgid cell membrane, the plasma network retracted to the central mass around the nucleus. New-formation depended on the extent of injury; it could consist in the differentiation of a new cell wall from the vesicular periphery of the central mass, the discarding of the old cell wall, and the subsequent development of staborgan, flagellum, and remaining structures. In its most complete expression, experimental reorganization seems to simulate the changes occurring in the

division process. Cienkowski went further in making experimental tests of the regenerative potencies of various fragments, concluding, "Even in very minute bits of protoplasm the essential organelles of *Noctiluca* can be formed *de novo*." (p. 52). The most extensive cytological study of *Noctiluca* was made by Pratje (1921). His observations on regeneration were limited to an account of the replacement of an injured cell membrane and its derivative, the staborgan. He recorded the migration of central plasma and nucleus to an injured site, where cytoplasmic threads were sent out, and the subsequent return of these wandering elements to a sub-cytostomal position.

A novel approach was employed by Hübner (1902) on a complex colonial phytomonad, *Volvox globator*. He tested the ability of somatic cells to restore experimentally removed sectors of the spherical colonies, which are composed of somatic and germinal cells. In more than 200 operations of various kinds, isolated groups of somatic cells failed uniformly to regenerate mutilated colonies. Individual cells were too small to test intracellular potencies. Without reference to the preceding, Bock (1926) worked on a series of colonial phytomonads: *Gonium pectorale*, *Pandorina morum*, *Eudorina elegans*, and *Volvox aureus*; only the last possesses germinal and somatic differentiation. By testing the reactions of isolated cells, he sought to determine whether the Volvocidae represented colonial or multicellular individuals. He found that with advancing complexity in the series, the effects of mutilating colonies became increasingly severe. Thus while cells of *Gonium* and *Pandorina* regularly restored entire colonies, *Eudorina* cells produced only incompletely formed dwarf colonies, and *Volvox* cells died with no evidence of multiplication. These experiments indicate that mature somatic cells of the Volvocidae cannot regenerate a colony. It should prove interesting to trace this reaction back through the earlier stages of differentiation in a *Volvox* colony. Pietschmann (reported in Przibram, 1909, p. 8) found that operations on young daughter-colonies of *Volvox* produced the same negative effect as in Hübner's experiments, but apparently no attempt was made to test cleavage stages.

(2). *Sarcodina*

Of the Sarcodina the relatively simple Amoebida were among the first used for regeneration studies. Greeff (1867) effected fragmentation in a large unnamed form (probably *Pelomyxa*), with the result that most of the fragments developed into completely normal individuals. Unaware of the multinucleate condition of *Pelomyxa*, Greeff concluded simply that experimental divisibility was probably widespread among Rhizopoda. A. Gruber (1886) amplified this finding in his study of *Amoeba proteus*. He showed that while nucleate pieces regenerated normally, enucleate individuals became spherical and died within a few days.

Subsequent workers have used amebae for various experimental purposes; some of the results seem pertinent to the problem of the rôle of the nucleus and cytoplasm in regenerative processes. Through his extensive experiments on *A. proteus*, Hofer (1890) undertook to reinvestigate the problem of nuclear versus cytoplasmic control of various cellular functions. His protocols of regeneration added a more detailed analysis of Gruber's results. LeDantec's study of digestion (1894) revealed only the fact that enucleate *A. proteus* and *Gromia*

fluviatilis could not assimilate and consequently degenerated. Penard's treatise on rhizopods (1902) recorded fragmentation of *Pelomyxa* spp. and *A. fluida* under unfavorable conditions, and the regeneration of nucleate pieces (p. 142). His observations of pellicular amebae (1905) disclosed that enucleate *A. terricola* could heal a mutilated pellicle, but it survived only five days. Grosse-Allermann (1909) was able to keep enucleate fragments of this species alive for 25 days without observing regeneration. Štolc (1910) recorded the culture of enucleate *A. proteus* for 30 days. He claimed that digestion occurred in these fragments without the subsequent assimilation necessary for regeneration.

K. Gruber (1912) noted that removing a portion of the cytoplasm of *A. proteus* resulted in a corresponding decrease in nuclear volume. This supplied evidence of a physical interaction between cytoplasm and nucleus, quite apart from any chemical interchange which may occur during periods of morphogenesis. Willis' observations on the behavior of *A. proteus* (1916) included the interesting fact that only nucleate pieces could attach to the substratum (which Dellinger, 1906, had shown to occur in normal locomotion). This is probably a factor in explaining the normal behavior and survival only of nucleate fragments.

The regeneration process was used by Hartmann (1924; 1928) to act as a substitute for normal binary fission in *A. proteus* and *A. polypodia*. By regularly removing a small amount of cytoplasm before the time of normal division, he was able to inhibit reproduction during the four months' duration of his experiments. This was for Hartmann an experimental demonstration of the potential immortality of protozoan individuals, amplifying Weismann's well-known theoretical considerations of the potential immortality of a clone of Protozoa. Work on ciliates has extended this approach (see Bauer and Granowskaja, 1934). The less complete results of Phelps (1926) for *A. proteus*, during an experimental period of 32 days, corroborated the above findings.

In amebae regeneration obviously can apply only to restoration of cytoplasm, and possibly of a new cell membrane at a site of injury. The shell-formations of the Testacea and Foraminifera introduce additional derived structures for experimentation. The shells of Testacea are composed either of chitinoid membranes (*Arcella*, etc.), secreted platelets (*Euglypha*, etc.), or foreign accretions (*Difflugia*, etc.). Verworn (1888) could observe no shell regeneration in experimentally mutilated *D. urceolata*. Penard (1900) reported similarly for four other species of *Difflugia*, and Okada (1930) for a fifth; while Martini (1905) and Hegner (1920) added similar observations for five species of *Arcella*. In all instances the mutilations were preserved and adjustments in behavior resulted.

The more complex Foraminifera have yielded some important data bearing on regeneration. Dujardin (1835) was probably the first to observe the continued activity of crushed fragments of a species of the Miliolidae, without pursuing the implications of this fact (p. 351). There followed a series of reports treating of regenerative growth in Foraminifera. From a study of preserved shells, Carpenter, Parker and Jones (1862) gave a description of the regeneration of mutilated chambers in *Orbitolites* sp. They likened the process to the healing of an ulcerated surface. The Challenger expedition material studied by Carpenter (1883) and Brady (1884) furnished additional evidence that *Orbitolites* possesses great regenerative ability. In *O. tenuissima*,

for example, Carpenter reported that ". . . even a mere fragment broken away from the margin of a disk may suffice to originate a new one" (p. 19).

Bütschli (1886) made the important observation on normal young specimens of *O. complanatus* that its nuclei tended to accumulate peripherally at the site of shell secretion. This fact was corroborated by Verworn (1888) and by Rhumbler (1902) for several Foraminifera. Verworn's analysis of shell regeneration in *Polystomella crispa* showed further that regeneration in the former case alone probably rests, therefore, on the different developmental potentialities of the two groups of organisms.

Rhumbler's exhaustive study of shell-formation in Foraminifera (1902) led him to support Verworn's view that the foraminiferan nucleus plays a direct secretory rôle in the regenerative process. The only negative record seems to be Schultz's experimental study (1915) on *Astrorhiza limicola*. Excision of radial projections from the shell (through which

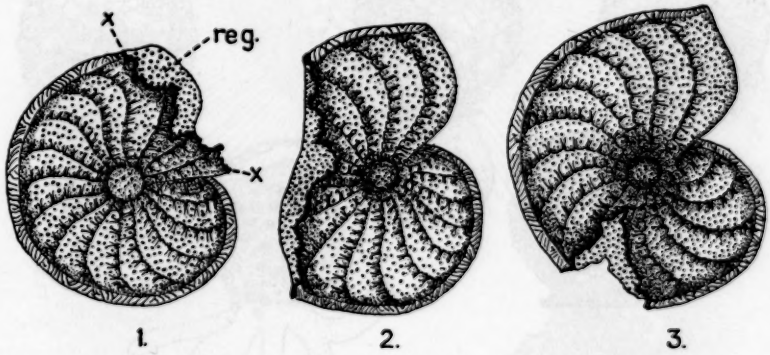

FIG. 1. THREE CASES OF REGENERATION FOLLOWING EXCISIONS IN A FORAMINIFERAN, POLYSTOMELLA (= ELPHIDIUM) CRISPA

Note that in each case the newly forming shell is secreted as a calcareous mass which is held in common by all of the cut chamberlets. *x*.....*x* = line of excision; *reg.* = regenerating shell. (After Verworn, 1888, redrawn and slightly modified.)

nucleate fragments uniformly repaired shell injuries, while enucleate individuals survived almost three weeks without any evidence of regeneration (Fig. 1). This was apparently clear-cut evidence of secretory activity of the nucleus in shell-formation. Comparing this case with the wholly negative results he obtained in Testacea, Verworn pointed out that whereas the foraminiferan shell continues to grow during most of its lifetime, the testacean shell is completely formed in one step at periods of cell division (Fig. 2). The existence of the capacity for rhizopodia are normally extruded) evoked local healing but no regeneration. Since *Astrorhiza* is known to have a highly variable shell contour, no integral loss to the organism was involved in these experiments. It is surprising that further investigations have not been undertaken on such excellent research material, especially in view of the current emphasis on morphogenetic studies.

The axopodia-bearing Heliozoa were experimented upon as early as 1867, when Greeff effected fragmentation in *Actinosphaerium eichhornii*. As in the previously

cited case of *Pelomyxa*, he noted no connection between survival and the composition of the viable fragments. Brandt (1877) repeated these experiments. He became the first protozoölogist to state that only nucleate fragments survive and regenerate: "This series of changes [i.e., regeneration] occurs only in fragments containing at least one nucleus; enucleate fragments and isolated nuclei themselves degenerate" (p. 30–1).

nucleate base, erect stalk and a capitate upper end bearing skeletal plates and axopodia. Zülzer's lengthy study of this form (1909) included a few regeneration experiments. Of 18 decapitated individuals, 3 survived; each regenerated a complete "head," with new central kinetic granule, axopodia and peripheral platelets. The removed enucleate "heads" did not regenerate, but died after a brief time. More experimental work is needed

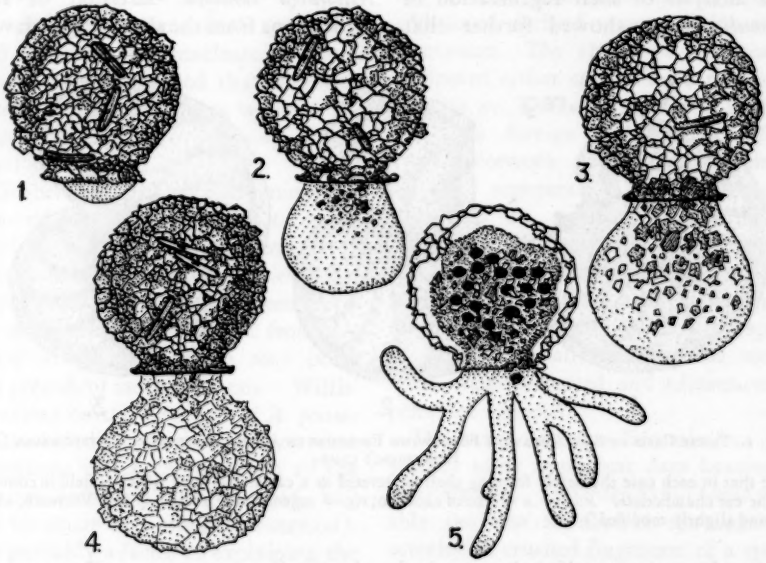

FIG. 2. ASEXUAL REPRODUCTION IN A TESTACEAN, DIFFLUGIA URCEOLATA

1–4. The newly forming shell is constructed from foreign particles held in reserve by the parent. 5. A dissected individual showing normal extrusion of pseudopodia. (After Verworn, 1888, redrawn.)

Gruber's work on *Actinophrys sol* (1883 a and b) stands in direct contradiction to this view, but Gruber himself soon afterward modified his opinion that the nucleus participated only in the reproductive function. His data were not convincing, being limited to a brief observation of supposedly "normal" enucleate fragments.

Wagnerella borealis is a remarkably differentiated, sessile heliozoan; it has a

on this genus to establish its complete regenerative potencies, and to investigate the cytological aspects of reconstitution.

The highly evolved Radiolaria have yielded very few studies of regeneration, but these indicate the favorable nature of such material. Schneider (1867) removed the central capsule from *Thalassicolla nucleata*, a peripylean type. This nucleate mass was viable, restoring the missing layer of extra-capsular cytoplasm and

axopodia, and assuming a normal vegetative existence (Fig. 3). This provided the first proof of the dominant rôle of the central capsule in the radiolarian organization, in contradiction to Haeckel's view that extra- and intra-capsular regions represented two independent unities. The less complete observations of Cienkowski

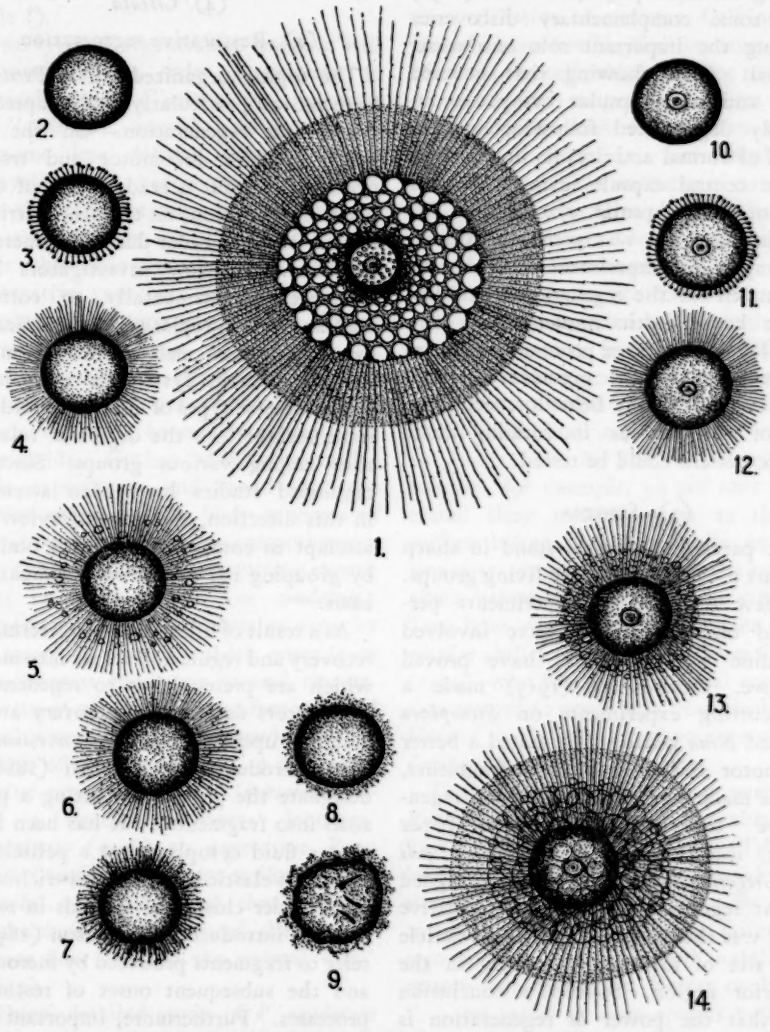

FIG. 3. THE REGENERATIVE RESPONSE IN A RADIOLARIAN, THALASSICOLLA NUCLEATA

1. A normal individual in cross-section, showing the nucleus within the central capsule. 2–9. Granular degeneration of an isolated central capsule following extirpation of the nucleus. 10–14. Normal regeneration in an intact central capsule. (Based on Verworn, 1892, redrawn and modified.)

(1871) and Hertwig (1876) corroborated Schneider's results.

Using the same species, Verworn (1892) made some complementary discoveries attesting the important rôle of nuclear material. After showing that isolated extra- and intra-capsular cytoplasm invariably degenerated following a brief period of normal activity, he implanted a foreign central capsule into an isolated mass of extra-capsular cytoplasm. The resulting complex was perfectly normal. An important experiment still to be undertaken for the regeneration problem is the heteroplastic implantation of a central capsule. Since pronounced species-differences occur in pigment distribution, external form, behavior, etc., the rôle of the nucleus in forming their specific pattern could be tested.

(3). *Sporozoa*

The parasitic Sporozoa stand in sharp contrast to the previous free-living groups. The few regeneration experiments performed on these forms have involved cephaline gregarines and have proved negative. Dembowski (1913) made a few cutting experiments on *Stenophora juli* and *Nina gracilis*. He noted a better locomotor ability in anterior fragments, but he made no comments on their regenerative capacities. Sokoloff's paper (1924) included experiments on *S. juli* and *Gregarina salpae* which were designed to test regeneration. The only positive result was the healing of mutilated cuticle at a site of injury, particularly in the posterior region. Sokoloff's conclusion was that the power of regeneration is poor in these parasitic forms. Although his conclusion may prove correct, yet his inability to culture even normal individuals and his failure to supply a nutrient medium make desirable a more carefully controlled series of experiments on Sporozoa.

(4). *Ciliata*

(a). Restorative regeneration

The highly organized ciliate Protozoa have proved particularly well adapted for studies on regeneration. On the one hand, complex locomotor and trophic organelles permit a ready study of cytoplasmic restitution; on the other, striking nuclear changes occur during regenerative processes. Yet few investigators have attempted experimentally to correlate nuclear and cytoplasmic reorganization by some causal mechanism. From another approach, systematic experiments on the diverse types of ciliates should give some insight into the degree of relationship among various groups. Since no organized studies have been attempted in this direction, the present review will attempt to compensate for this omission by grouping the results on a comparative basis.

As a result of injury, factors determining recovery and regulation are set into motion which are prerequisites to regeneration. The factors determining recovery are the first to operate following *merotomy* (a term introduced by Balbiani (1888) to designate the process of cutting a protozoan into fragments). It has been found that a fluid cytoplasm, or a pellicle rendered less elastic by peripheral trichocysts, may hinder closure of wounds in *merozoa* (a term introduced by Johnson (1893) to refer to fragments produced by merotomy) and the subsequent onset of restorative processes. Furthermore, important regulatory processes are involved in cytoplasmic movements repairing body shape, and in readjustments of osmotic relations, of locomotor coördination and of the size of organelles. A combination of these

factors probably explains why some closely related types have reacted so differently to experimentation (cf. Table I).

Two types of regenerative response will be considered in order, a reaction to physical injury ("restorative regeneration," Morgan, 1901a), and a response to some less definite, internal cause ("physiological regeneration"). Wherever the data permit, regenerative responses of a given genus will be treated under the following headings: general regenerative capacity; the mechanics of the regenerative process; and the rôle of the nuclear apparatus.

(1). Regeneration in vegetative individuals

Paramecium was one of the first holotrichous ciliates to be used for regeneration experiments. Gruber (1886) performed a single experiment, and found that the anterior region of the body regenerated in one day. Balbiani's comprehensive study (1893) included mass cutting experiments on *P. "aurelia"* (= *caudatum*). Its extremely slight regenerative capacity was traced in part to a thick outer layer of trichocysts hindering wound closure. Restoration of normal form often required several generations, and depended on the presence of abundant food. A few comparative experiments on *P. bursaria* indicated a similar response. Jennings' experiments (1908) on vegetative *Paramecium* (*caudatum* ?) were uniformly unsuccessful. He concluded that "Whenever the ectosarc is punctured, the internal contents flow out and the animal dies" (p. 615).

Calkins' detailed study of *P. caudatum* (1911b) involved hundreds of individuals cut in various ways. About 30 per cent remained active after 4 hours, but of 149 selected experimentals only 4.7 per cent regenerated. In the giant races which he used, however, regeneration varied from 1 per cent in one race to 100 per cent in a fourth. To explain the characteristic unequal fission of merozoa, Calkins postulated an irreversible division zone in the center of the cell which was not regulated to suit a given exigency. Peebles (1912) independently confirmed Calkins regarding racial variation, but emphasized that in all cases the outcome of merotomy depended on the physiological condition of the individuals used. Thus a viscid cytoplasm and abundant food ensure regeneration in 90 per cent of the cases, while young, less viscid cells perish in the same proportion because of diffluence. The general regenerative capacity was fair, even discounting her elimination of all individuals not surviving at least 24 hours. Of 83 individuals cut anteriorly, for example, 34 per cent regenerated their missing parts at the cut surface before dividing, while an additional 51 per cent divided in the original plane before any regeneration occurred. Two later workers reporting poor regenerative ability in this species were Chejfec (1932), who found that typical regeneration seemed to occur only posteriorly, and Hosoi (1937), who noted no regeneration during his study of behavior.

The most comprehensive work on *Paramecium* is the recent analysis by Tartar (1939). Using 7 species (Table I), he reinvestigated the alleged racial variation in regenerative capacity. By differentiating sharply between failure to recover from merotomy and inability to restore lost organelles, Tartar could find ". . . no racial or even species variation of a general ability to regenerate in the genus *Paramecium* as has been previously held." Of 865 anterior cuts, for example, he eliminated 356 as failing to survive; 98 per cent of the remaining merozoa

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Summary of investigations on regeneration in cili

PROTOZOAN	AUTHOR AND DATE	SCOPE OF WORK
Prorodon sp.	Blochmann (1887–89)	Effect of pressure on body
teres	MacDougall (1925)	Extent of regen.
Pseudoprorodon (= *P.*) *niveus*	Balbiani (1888)	Rôle of nuclear apparatus
Lacrymaria olor	Verworn (1888)	Rôle of nuclear apparatus
Spathidium "spathula"	Moody (1912)	Interdiv. age and regen. capacity
spathula	Moore (1924)	Regen. during life history
"Amphileptus incurvatus" (?)	Lepsi (1926)	Occurrence of regen.
Loxophyllum meleagris	Holmes (1907)	Rôle of body movements in regen.
Dileptus anser	Balbiani (1893)	Extent of regen.
anser	Sokoloff (1924)	Extent of regen.
anser	Vápeník (1927)	Effect of repeated merotomy
Trachelius ovum	Balbiani (1888)	Rôle of nuclear apparatus
ovum	Hamburger (1903)	Check of Balbiani
Loxodes rostrum	Gruber (1886)	Extent of regen.
rostrum	Balbiani (1893)	Extent of regen.
Tillina magna	Gregory (1909)	Extent of regen.
Paramecium sp.	Gruber (1886)	Occurrence of regen.
caudatum	Balbiani (1893)	Extent of regen.
caudatum	Wallengren (1902)	Inanition phenomena
caudatum	Jennings (1908)	Inheritance of mutilations
caudatum	Lewin (1910)	Rôle of nuclear apparatus
caudatum	Calkins (1911b)	Extent of regen.
caudatum	Peebles (1912)	Extent of regen.
caudatum	Chejfec (1932)	Influence of envtl. factors
caudatum	Schwartz (1934)	Rôle of Mi
caudatum	Hosoi (1937)	Cyclosis in merozoa
caudatum	Tartar (1939)	Reinvestigation of "regen. power"
bursaria	Balbiani (1893)	Extent of regen.
bursaria	Tartar (1939)	See *P. caudatum*
aurelia	Tartar (1939)	*caudatum*
trichium	Tartar (1939)	*caudatum*
polycaryum	Tartar (1939)	*caudatum*
woodruffi	Tartar (1939)	*caudatum*
P. multimicronucleatum	Tartar (1939)	*caudatum*
Frontonia leucas	Gruber (1886)	Extent of regen.
leucas	Balbiani (1888)	Rôle of nuclear apparatus
leucas	Popoff (1908)	Nucleo-plasmic ratio and fission
leucas	Sokoloff (1924)	Extent of regen.
sp.	Hartmann (1922)	Occurrence of regen.
Glaucoma scintillans	Prowazek (1901)	Rôle of nuclear apparatus

TABLE I

Protozoa, arranged according to taxonomic relationships

GEN. REGEN. CAPACITY	RÔLE OF NUCLEAR COMPLEX	REMARKS
		Regen. of new pellicle and cilia Few, unsystematic experiments
Good	Regen. only in nucleate merozoa	
	Regen. only in nucleate merozoa	Incidental experiments
Good		Few experiments; supports Calkins ('11a) Poor regen. capacity during conj.
	Regen. only in nucleate merozoa	Few (one?) experiments
Good		Movements comprise secondary factor
Good		Very rapid regen.
Good	Partial regen. in enucl. merozoa	Evidence not convincing
Good		More rapid regen. Few experiments
Fair	Regen. only in nucleate merozoa	Few experiments
Good	Presence of Ma necessary	More extensive than above
Negative		Few experiments
Good		Slow regen. (4–5 days)
Fair		Few experiments
		1 experiment; ant. end regenerated
Poor	Regen. only in nucleate merozoa	Nuclear control of regen. believed lost
	Ma degenerates; Mi unaffected	Hunger-changes are reversible
Negative		Death invariably follows merotomy
	Regen. of a-Mi merozoa with Ma	Limited viability of a-Mi clone
Poor		Racial variation in regen. capacity
Fair		Indiv. variation in regen. capacity
Poor		Hunger and lower pH favor regen.
	Mi is important for viability	Brief report; supports Lewin ('10)
Negative		No regen.; cyclosis normal in merozoa
Good		Importance of survival factor noted
Poor		Few experiments
Good	Regen. only in nucleate merozoa	Zoöchlorellae do not aid viability
Good		See *P. caudatum*
Good		See *P. caudatum*
Good		See *P. caudatum*
Good		See *P. caudatum*
Good		See *P. caudatum*
Poor		Few experiments
Poor	Regen. only in nucleate merozoa	Regen. only after transverse cuts
	N.-p. ratio controls fission	Incidental reference to regen.
Fair		
Negative		Failed to survive merotomy
	Regen. only in nucleate merozoa	Few, unsystematic experiments

PROTOZOAN	AUTHOR AND DATE	SCOPE OF WORK
Colpidium colpoda	Balbiani (1893)	Extent of regen.
Spirostomum ambiguum	Gruber (1886)	Extent of regen.
ambiguum	Balbiani (1888)	Rôle of nuclear apparatus
ambiguum	Sokoloff (1924)	Extent of regen.
ambiguum	Seyd (1936)	Regulation of injuries
Blepharisma undulans	Moore (1924)	See *Spathidium*
undulans	Nadler (1929)	Induction of regen. of pellicle
Condylostoma sp.	Tartar (1938b)	Quantity of Ma and regen.
Climacostomum virens	Gruber (1886)	Extent of regen.
Fabrea salina	Balbiani (1893)	Rôle of nuclear apparatus
Stentor coeruleus	Gruber (1885a)	Extent of regen.
coeruleus	Gruber (1885b)	Rôle of nuclear apparatus
coeruleus	Gruber (1886)	Extent of regen.
coeruleus	Verworn (1888)	Rôle of nuclear apparatus
coeruleus	Schuberg (1890)	Site of anlage in div. and regen.
coeruleus	Balbiani (1891b)	Analysis of "double monster"
coeruleus	Balbiani (1892)	Rôle of nuclear apparatus
coeruleus	Johnson (1893)	Extent of regen.
coeruleus	Lillie (1896)	Minimal reorganization mass
coeruleus	Morgan (1901b)	Proportionate regen. of structures
coeruleus	Stevens (1903a)	Mechanism of peristome regen.
coeruleus	Prowazek (1903a)	Rôle of nuclear apparatus
coeruleus	Popoff (1909)	Relation of nuclear to body size
coeruleus	Ishikawa (1912)	Healing and regen. processes
coeruleus	Prowazek (1913)	Form-determination ("Morphe")
coeruleus	Hartmann (1922)	Repeated regen. versus fission
coeruleus	Burnside (1929)	Relation of nuclear to body size
coeruleus	Causin (1931)	Similarities between div. and regen.
coeruleus	Hetherington (1932)	Relation of envt. to physiol. regen.
coeruleus	Schwartz (1934; 1935)	Rôle of Ma and of Mi in regen.
polymorphus	Gruber (1886)	Extent of regen.
polymorphus	Balbiani (1893)	Rôle of nuclear apparatus
polymorphus	Lillie (1896)	Minimal reorganization mass
igneus	Balbiani (1893)	Rôle of nuclear apparatus
Bursaria truncatella	Lund (1917)	Normal versus experimental reorgn.
truncatella	Joff (1923)	Rôle of mitochondria in regen.
truncatella	Sokoloff (1924)	Extent of regen.
truncatella	Schmähl (1926)	Mechanism of peristome formation
truncatella	Hartmann (1922)	Occurrence of regen.
Licnophora auerbachii	Stevens (1903b)	Extent of regen.
macfarlandi	Balamuth (1939)	Extent of regen.
Uroleptus mobilis	Calkins (1921)	Effect of merotomy during conj.
mobilis	Tittler (1938)	Regen. after injury by electricity
Urostyla grandis	Fauré-Fremiet (1910)	Regen. response and stage of div.

TABLE I—*continued*

GEN. REGEN. CAPACITY	ROLE OF NUCLEAR COMPLEX	REMARKS
Negative		Few, unsystematic experiments
Negative		Rapid disintegration of merozoa
Good	Regen. only in nucleate merozoa	1 case of incomplete, enucleate regen.
Good		Middle-third region regenerates best
Fair		Regulative regen. of peristome noted
Good	Presence of Ma necessary	Regen. of a-Mi dividing forms
		Pellicle can be shed and regenerated
	Regen.-time is function of Ma vol.	Various types of abnormal regen. noted
Good		Regen. in 24 hours; few experiments
Good	Regen. only in nucleate merozoa	Few experiments
	"Nucleus not necessary for regen."	Brief report; few data
Good	"Nucleus is necessary for regen."	Reversal of opinion in '85a
Good	Regen. only in nucleate merozoa	Only few new experiments
	Regen. only in nucleate merozoa	Incidental experiments
		Few experiments; confirms Gruber ('86)
	Dual nuclear apparatus causal	Monster formed by incomplete merotomy
Good	Ma believed to control regen.	Exhaustive study at various stages
Good		Confirms Balbiani independently
Good	Regen. only in nucleate merozoa	Min. regen. mass is $\frac{1}{27}$ original mass
Good	Regen. only in nucleate merozoa	Proportionate regulation noted
Good	Regen. under nuclear influence	Some regen. in enucleate merozoa
	Partial regen. in enucl. merozoa	Poor factual evidence
	"N.-p. ratio controls regen."	Heritable size-differences produced (?)
		Regen. of lost membranelles in situ
		Ectoplasm controls "Morphe"
Good		Repeated regen. substituted for div.
Good	Regen. only in nucleate merozoa	No heritable size-differences produced
Good	Regen. only in nucleate merozoa	Regen. regarded as "abortive fission"
		No physiol. regen. in controlled media
Good	Ma alone is proved necessary	2 viable a-Mi clones produced
Good		Regen. within 24 hours
Good	Regen. only in nucleate merozoa	Results as for *S. coeruleus*
Good	Regen. only in nucleate merozoa	Results as for *S. coeruleus*
Good	Regen. only in nucleate merozoa	Results as for *S. coeruleus*
Good		Dedifferentiation likened to autolysis
		Mitochondria accumulate at wound
Fair	Partial regen. in enucl. merozoa	Evidence is questionable
Good	Presence of Ma held necessary	Disagrees with Sokoloff's results
		Encysted following merotomy
Limited	Ma and Mi held necessary	Observations incomplete
Good	Ma alone is proved necessary	Basal disc is never regenerated
Good		Reorgn. without cross-fertilization
		Favors necessity of Ma and Mi in regen.
		Notes stage of irrevers. determination

TABLE I

PROTOZOAN	AUTHOR AND DATE	SCOPE OF WORK
Amphisia (?) sp.	Dembowska (1926)	Comparison with *Stylonychia*
Stylonathes sterkii	Garnjobst (1937)	Regen. after accidental injury
Pleurotricha sp.	Hewitt (1914)	Behavior of Mi in regen.
Gastrostyla (?) *vorax*	Nussbaum (1884; 1886)	Limitations of regen. capacity
sp.	Bauer & Granowskaja (1934a)	Nuclear and respiratory changes followi merotomy
sp.	Bauer & Granowskaja (1934b)	Dependence of "indiv. immortality" o interdiv. age in regen.
Oxytricha fallax	Ishikawa (1912)	Healing and regen. processes
fallax	Reynolds (1932)	Rôle of Mi
sp.	B. & Gr. (1934a & b)	See *Gastrostyla*
Actinotricha sp.	Dembowska (1926)	Comparison with *Stylonychia*
Stylonychia pustulata	Dujardin (1841)	Effect of mutilation
pustulata	Prowazek (1898)	Occurrence of regen.
mytilus	Balbiani (1899)	Action of salt solutions
mytilus	Prowazek (1903b)	Regen. during "depression"
mytilus	Lewin (1911)	Behavior of Mi in regen.
mytilus	Ishikawa (1912)	Healing and regen. processes
mytilus	Dembowska (1925)	Comparison of fission with regen.
mytilus	Young (1926)	Behavior of nuclei in regen.
mytilus	Dembowska (1938)	Effect of hunger on reorgn.
Diophrys sp.	Dembowska (1926)	Comparison with *Stylonychia*
Uronychia transfuga	Calkins (1911a)	Interdiv. age and regen. capacity
transfuga	Dembowska (1926)	Comparison with *Stylonychia*
setigera	Young (1922)	Reinvestigation of Calkins
setigera	Dembowska (1926)	Comparison with *Stylonychia*
binucleata	Young (1922)	Rôle of Mi
uncinata	Taylor (1928)	Comparison of fission with regen.
Euplotes patella	Taylor (1920)	Function of neuromotor system
patella	Taylor (1923), and Taylor & Farber (1924)	Rôle of Mi
patella	Reynolds (1932)	Rôle of Mi
charon	Dembowska (1926)	Comparison with *Stylonychia*
vannus	Dembowska (1926)	Comparison with *Stylonychia*
Zoothamnium alternans	Summers (1938a & b)	Normal and regulative growth
Vorticella sp.	Runyan & Torrey (1914)	Regulatory development of cilia
Unidentified ciliates	LeDantec (1897)	Behavior of nuclear apparatus
Anoplophrya filum	Sokoloff (1924)	Extent of regen.
Opalina ranarum	Nussbaum (1884; 1886)	Extent of regen.
ranarum	Joff (1923)	Rôle of mitochondria in regen.
ranarum	Sokoloff (1924)	Extent of regen.

TABLE I—*Concluded*

GEN REGEN. CAPACITY	RÔLE OF NUCLEAR COMPLEX	REMARKS
		Few, unsystematic experiments
		Regen. occurs normally within cyst
		No. of Mi remains constant (Lewin, '11)
	Regen. only in nucleate merozoa Nuclear changes only in "adult" merozoa	First such proof for ciliates Marked increase in respiration in "adult" merozoa Only "adult" individuals survive repeated merotomy
Good	Ma and Mi held necessary	Describes healing process Supports Dembowska ('25) See *Gastrostyla*
		Few, unsystematic experiments
		Hypothecates regen. of merozoa
	Regen. only in nucleate merozoa	Few, unsystematic experiments
Good	Regen. only in nucleate merozoa	Slow dissolution of body in salt soln.
Good		Incomplete set of observations Mi divide in ±50% cases of merotomy
		Reports regen. of 2 enucl. merozoa
Good	Regen. only in nucleate merozoa	Div. and regen. follow similar course
Good		Simult. nuclear and cytoplasmic reorgn.
		"Physiol. regen." is due to hunger
Good		Supports work on *Stylonychia*
Good	Ma alone is nec. at maturity	Regen. capacity is best at time of div.
Good	Ma and Mi must be present	Supports Calkins on vegetative forms
Good	Ma and Mi necessary in division	Supports Calkins fully
Good	Ma and Mi seem to be necessary	
Good		Additional corroboration of Calkins
Good		Condens.-dispers. theory of reorgn.
		Incidental references to regen.
	Mi is essential for viability	A-Mi merozoa die after max. of 2 divs.
	Ma and Mi must be present	Evidence of racial variation
	Ma and Mi must be present	Few experiments. Regen. is slow
	Ma and Mi must be present	Few experiments. Regen. is slow
Good		Term. macrozoöid exerts physiol. dom.
		Stalk exerts dom. effect
	Holds that Ma regenerates new Mi	Data are unreliable
Poor		Posterior region regenerates best
Negative		Disintegration without healing Mitochondria accumulate at wound
Very poor		Few cilia appear at cut surface

regenerated and divided. These data seem to indicate that the condition of given individuals may be a decisive factor in determining the outcome of merotomy. Tartar dissociated the rapid regeneration of mouth and gullet as a primary response from the secondary regulation of cell shape, the latter occurring only after feeding had begun. In all instances the missing parts were formed directly at the cut surface (Fig. 4). As Tartar's work is not favorable for experimentation. Lewin (1910) was able to culture certain amicronucleate fragments of *P. caudatum* in which part of the macronucleus remained. The resulting clones had a low division rate, possibly due to the absence of the micronucleus. Schwartz (1934) confirmed this observation in a brief report; he found that an amicronucleate race divided subnormally for two months before succumbing. A recent personal

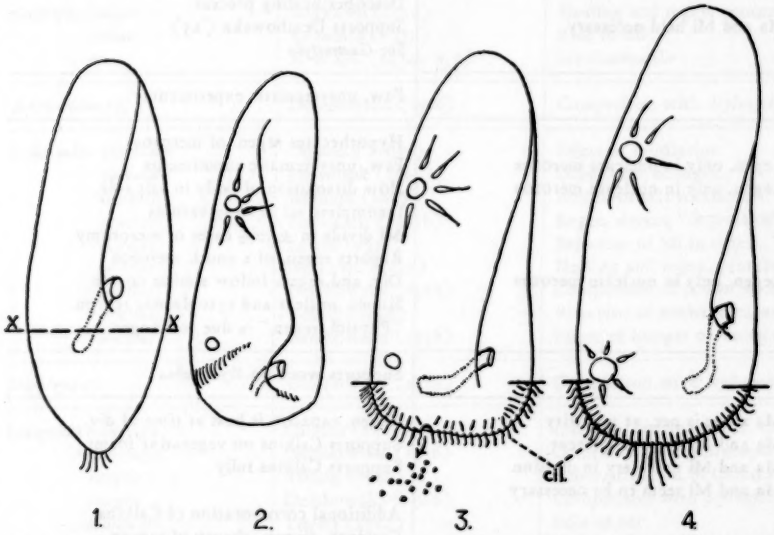

FIG. 4. EARLY STAGES IN THE REGENERATION OF THE POSTERIOR END OF A HOLOTRICHOUS CILIATE, PARAMECIUM MULTIMICRONUCLEATUM

1. Level of cut, not showing the intact nuclei. 2–4. Appearance of merozoön 2, 5 and 19 hours after cutting. Note the gradual increase in size during regeneration. *x*.....*x* = plane of transection; *cil.* = regenerating cilia. (After Tartar, 1938a, redrawn.)

indicates, *Paramecium* does not constitute a unique case among ciliates, as had been claimed by some, but rather it belongs to a group in which the factor of healing segregates a large class of individuals at the outset.

The nuclear apparatus of *P. caudatum* consists of a centrally located, oval macronucleus and a single micronucleus. Accordingly, only middle portions of the body contain nuclear material, and this communication from Schwartz (March, 1939) indicates that he has been able also to produce amicronucleate *P. bursaria*, which are "bisher ganz gut lebensfähig." One is led to infer that the macronucleus alone is essential for regeneration, disregarding the factors essential for viability.

Other Holotrichida have been studied in less detail. In a closely related genus, *Tillina magna*, Gregory (1909) noted only

a fair regenerative ability, although the rapid reconstitution required only 24 hours. Balbiani contributed, in all, studies on regeneration of 14 ciliates. In his earliest work in this connection (1888), using the prostomatous *Prorodon* (= *Pseudoprorodon*) *niveus*, he showed that only nucleate fragments regenerated, completing the process within 3 hours. He noted that the cut surfaces of enucleate merozoa never truly healed; the formation of contractile vacuoles in these fragments was explained as a purely physical process, due to local dilatation in one of the remaining radiating canals. Bütschli (1887–89) recorded an interesting observation by Blochmann on *Prorodon* sp. Under the impact of pressure, the entire pellicular layer together with the cilia separated from the body and were quickly replaced by regenerated structures. In the related *Prorodon teres*, MacDougall (1925) contributed a few experiments indicating that small anterior pieces (presumably enucleate) do not regenerate, while posterior nucleate pieces regenerated completely in 24 hours. Verworn's results on *Lacrymaria olor* (1888) and Lepsi's short account of "*Amphileptus incurvatus*" (?) (1926) confirmed the occurrence of regeneration only in nucleate merozoa.

Moody (1912) briefly described regeneration of *Spathidium* "*spathula*" (= sp.) during the interdivisional period. Her few results supported Calkins' work on *Uronychia* (see below), since individuals approaching fission were shown to have the greatest regenerative capacity. Moore (1924) operated on *S. spathula* during various phases of its life-history. Vegetative individuals dedifferentiated completely and then regenerated rapidly, but subsequent fission was delayed until a general restorative growth had occurred.

Holmes (1907) approached the problem of regeneration in *Loxophyllum meleagris* by studying the rôle of cytoplasmic movements in merozoa. His results indicated that their rôle was subordinate to the actual differentiation of new structures, consisting chiefly in "pulling the body into shape" after missing organelles had been restored.

In a related form, *Dileptus anser*, Balbiani (1893) discovered an extremely well-developed regenerative capacity, possibly correlated with the presence of many macronuclei; four fragments of one individual regenerated within four hours. Sokoloff's results (1924) confirmed these findings. He referred to regeneration in enucleate fragments, but his data show that he failed to distinguish between regeneration and regulation. Vápeník's study (1927) of the effect of repeated merotomy on the speed of regeneration cannot be considered complete, since *D. anser* did not survive more than five operations within ten days (*cf.* Dembowska, 1925, on *Stylonychia:* repeated regeneration of an individual undergoing 50–60 consecutive operations; also see below). Vápeník's data showed at most that complete regeneration occurred more rapidly after the second and third operations than after the first.

Trachelius ovum was shown by Balbiani (1888) to regenerate only after transection. Hamburger (1903) demonstrated, however, that careful technique ensured successful operations of all kinds, as in *Dileptus*.

Gruber's few experiments on *Loxodes rostrum* (1886) were negative, since merozoa did not survive merotomy. Balbiani's technique (1893) proved more suitable, and regeneration occurred as a rule, although it required at least four or five days. As in *Paramecium*, the restoration of missing structures appeared to take place directly at the cut surfaces (Fig. 5).

Experiments with the oral membrane-

bearing Hymenostomina have contributed few satisfactory data. *Frontonia leucas* regenerated poorly in Gruber's few experiments (1886), deformities being retained for a long time. Balbiani's account (1888) added little to this. Transected nucleate fragments regenerated in 24–48 hours if at all, poor healing properties explaining the frequent failure to recover. Sokoloff's similar results (1924) added the observation that nuclei were readily extruded from merozoa, thereby preventing regeneration. Hartmann (1922) obtained wholly negative results in his experiments on *Frontonia* sp., since merozoa failed to survive merotomy. Popoff's study (1908) of the influence of the nucleoplasmic ratio on division included cutting experiments on *F. leucas*. Repeated operations following regeneration (process not analyzed) caused a delay in each successive regeneration, death occurring finally after five operations. Brief accounts of related forms include Prowazek's record (1901) that nucleate merozoa of *Glaucoma scintillans* regenerated, and Balbiani's few negative observations on *Colpidium colpoda* (1893), in which there was apparently no regeneration.

In these studies of holotrichous ciliates, there has been no evidence of a localized regenerative potency, nor does any region of the body seem to act as an organizing center for new oral and locomotor structures. Instead missing parts are formed *in situ* at rates depending on experimental conditions. Concerning the relative rôles of macronucleus and micronucleus, the work of Lewin and Schwartz makes it seem probable that the macronucleus alone is essential for the regeneration of missing structures. Whether such ami-

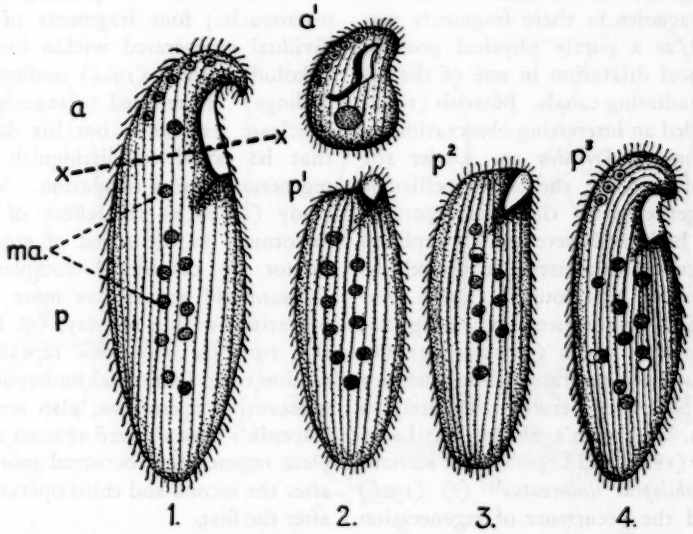

FIG. 5. THE COURSE OF REGENERATION OF THE ANTERIOR END OF A HOLOTRICHOUS CILIATE, LOXODES ROSTRUM

1. Level of cut (through oral region), showing scattered macronuclei and five Müller's vesicles. 2–4. Restorative process in anterior (a^1) and posterior (p^1–p^3) merozoa, illustrating the direct manner of replacement. x.....x = plane of transection; *ma* = macronuclei. (After Balbiani, 1893, redrawn and slightly modified.)

cronucleate individuals can produce viable races, however, is not yet proved.

Turning now to the more complex Spirotrichida, some interesting points of comparison are offered. Of the heterotrichous types, those possessing both cilia and derived organelles, the genus *Stentor* has been analyzed most completely. Its large size, pronounced polarity and multinucleate structure have made it a peculiarly favorable subject.

The inaugural work of Gruber (1885a and b; 1886) showed that *Stentor* regenerated readily after merotomy. He noted that excision of a portion of the adoral zone resulted in a fundamental reorganization; this involved the formation along the left side of the body of a longitudinal anlage which subsequently migrated to replace the remnant of the old adoral zone. This process was noticeably similar to normal fission, replacement being substituted for formation of a duplicate organization (Fig. 6). Reversing his earlier opinion (1885a), Gruber (1885b, etc.) came to the conclusion that nuclear material must be present for regeneration in vegetative individuals.

Further studies have added many data to each of these three important aspects of regeneration. Some general investigations include Lillie's observation (1896) that in *S. coeruleus* and *S. polymorphus* (used interchangeably) complete regeneration occurred only in nucleate fragments containing at least $\frac{1}{17}$ of the original body mass. Morgan (1901b) produced still smaller viable merozoa of *S. coeruleus* ($\frac{1}{8}\frac{1}{4}$ of the original mass), but pointed out the variables which weaken such an approach to the general problem of regeneration. His careful analysis of regenerating fragments showed that a precise mechanism adjusted the size of cytoplasmic organelles to conform with a newly acquired body size, whether this involved regulation of old or formation of new structures.

Schuberg's study of fission in *S. coeruleus* (1890) gave the first adequate account of that process. He checked and was able to confirm Gruber's report that a new adoral zone developed similarly in division and regeneration. Balbiani (1892) seems to have failed to witness the earlier stages of the migrating adoral anlagen in posterior merozoa, since he refers to their antero-dorsal origin in such fragments (p. 396). Morgan (1901b) and Stevens (1903a) contributed further analyses of regenerating adoral zones and of the regulation of form. Stevens noted in greater detail than other workers the regeneration of longitudinal myonemes and the rôle of cytoplasmic movements in peristome formation. Stevens' paper and that of Ishikawa (1912) described the regeneration of membranelles *in situ* between the cut ends of an adoral zone, but their evidence was not convincing. If these reports were true, it would mean that membranelles could regenerate by two entirely different methods, which would be unusual. It is noteworthy that Johnson's experiments (1893) had led him specifically to deny such an occurrence, pointing out the possibility of confusing the normal dorsal cilia with membranelles in contracted, cut individuals. Later researches have supported Johnson's position. Causin (1931) likened restorative regeneration to an "abortive fission"; he found that in both cases new membranelles formed only from a migrating anlage. The most recent work of Schwartz (1935) is also confirmatory. He established without any doubt, moreover, that the anlage replaces only the oral part of the adoral zone in regeneration (see Fig. 6).

The nuclear apparatus of *S. coeruleus* consists of a long beadlike chain of macro-

nuclear segments and a variable number of micronuclei (10–42). Verworn's few experiments (1888) confirmed Gruber's account of the necessity of nuclear material in regenerating vegetative individuals, and the great majority of investigators since that time seem to have established this point. Balbiani (1893) reached the same conclusion also for *S. polymorphus* and *S. igneus*. Prowazek (1903a), however, came to a different conclusion. Study of nuclear behavior led him to conclude that repeated injury and culturing at high temperatures resulted in the

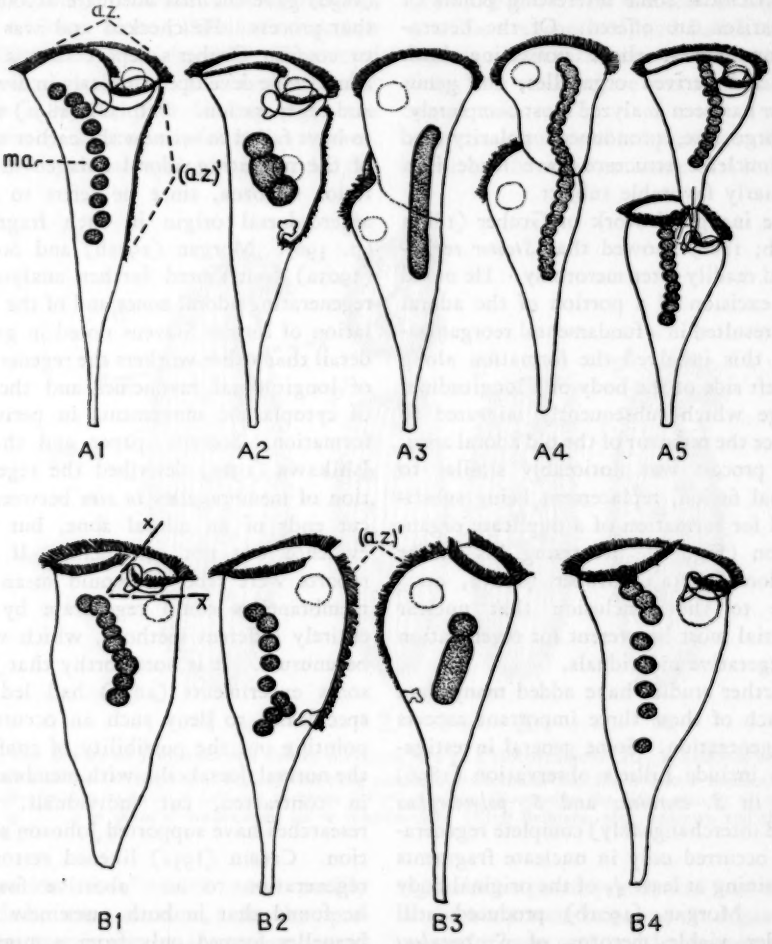

FIG. 6. COMPARISON OF THE COURSE OF FISSION (*A1-A5*) WITH RESTORATIVE REGENERATION (*B1-B4*) IN A HETEROTRICHOUS CILIATE, STENTOR COERULEUS

Note the general similarity in the sites of the oral anlagen and in the behavior of the macronuclei. *a.z.* = parental adoral zone; $(a.z.)^1$ = anlage of new adoral zone; *ma.* = macronucleus; *x*.....*x* = line of excision. (Based on Schwartz, 1935, redrawn and modified.)

regeneration of enucleate fragments; under these conditions "chromidia" given off to the cytoplasm were supposed to have permitted regeneration to occur. His data cannot withstand analysis. In 1913 Prowazek believed to have localized the seat of formative energy in the pellicle and ectoplasm, chiefly because operations removing much pellicle and ectoplasm proved fatal more often than the removal of endoplasm and some nuclear substance. He neglected the simpler explanation that operations of the first kind had so disrupted the regulatory osmotic mechanism as to cause death.

Granting the necessity for nuclear material, it has proved more difficult to determine the relative rôles of macronucleus and micronucleus. Balbiani (1892) emphasized nuclear behavior throughout his experiments. He showed clearly in regenerating *Stentor* that the elongate macronucleus underwent the same contraction ("balling") and re-segmentation as in fission (Fig. 6), being the first to describe this. Balbiani claimed that the macronucleus alone was essential to the regenerative process, but his only evidence was indirect, being derived from the conjugation process. Thus, cutting experiments on individuals in the stage of resorption of the old macronucleus (hence its "non-activity") resulted in no regeneration, while merozoa did regenerate when cut later during the formation of the new macronuclear anlage. Since both macronuclei and micronuclei reorganize simultaneously, however, Balbiani's conclusion favoring the macronucleus obviously is forced.

Schwartz (1934; 1935) was the first to approach the problem directly by attempting to produce amicronucleate and amacronucleate merozoa. By operating on dividing or regenerating individuals in which the macronuclear segments had "balled" together, he was able to remove the entire macronucleus and still leave from 1 to 16 micronuclei. In these amacronucleate experimentals digestion of food never occurred, nor was regeneration ever induced. In support of Stevens (1903a), however, it was observed that regeneration already in progress before the operation was performed might continue, which indicates the irreversibility of the process after it is once under way. Formation of contractile vacuoles in amacronucleate merozoa is explicable by recalling that they form through a purely physical process (cf. *Pseudoprorodon*, above). To produce amicronucleate individuals, Schwartz repeatedly removed a portion of the macronucleus together with a varying number of adjoining micronuclei. After each operation the remaining micronuclei divided only once; finally (after five operations) cytological examination of descendants of his experimentals showed that all the micronuclei had been removed. No differences in size or division rate could be noted between his two successfully cultured amicronucleate clones and normal controls. One of these clones propagated more than a year before its accidental elimination. If his data are correct, Schwartz's experiments constitute the first clear-cut demonstration of the relative rôles of the two nuclear elements in regenerating heterotrichs.

The relation of nuclear to body size in *Stentor coeruleus* has been studied by a few investigators. Popoff (1909) claimed that removal of most of the macronucleus caused such an abnormal shift in the nucleo-plasmic ratio as to result in death. Burnside's results (1929) contradict these data (as do also those of Schwartz (1935); etc.). Furthermore, the size of a biotype has never been changed experimentally by merotomy, contrary to Popoff's report.

The importance of the nucleo-plasmic ratio in cell division and regeneration has long been maintained by the R. Hertwig school. This problem cannot be discussed at length here, but it seems clear that at best the nucleo-plasmic ratio can comprise only part of a complex set of factors at work.

The results obtained in studies of several other heterotrichous ciliates seem to fit into the general scheme discussed above. Gruber's paper (1886) stated that *Climacostomum virens* regenerated lost parts within 24 hours. Balbiani (1893) reported a remarkable viability in *Fabrea salina*, nucleate merozoa regenerating readily. In a recent contribution by Tartar (1938b) on *Condylostoma* sp. (*magnum* ?), there was reported an effect by the amount of nuclear substance in regenerating individuals. Merozoa containing equivalent portions of cytoplasm but more macronuclear substance (in the ratio of two or three to one) regenerated on the average twice as rapidly as their sister-merozoa. This difference in speed was due to a difference in the "preparatory" period prior to regeneration (period of "labile equilibrium" of Sokoloff), since the actual time of differentiation after the first appearance of the regenerating anlage was the same in each instance.

Spirostomum has been studied by various workers. Gruber (1886) attributed his lack of success in experiments on *S.* sp. (*ambiguum* ?) to its poor viability in cultures. Balbiani (1888) apparently encountered less difficulty with *S. ambiguum*. Nucleate fragments regenerated within three hours, and contractile vacuoles formed even in enucleate merozoa. Sokoloff (1924) also found a well-developed regenerative capacity, particularly in the middle-third of the body. At the same time he confirmed reports of *Spirostomum's* sensitivity to environmental conditions. In 1936 Seyd investigated regulative processes accompanying regeneration. A definite regulative agency appeared to be at work, since disproportionately situated peristomes dedifferentiated and new ones formed at the normal body level.

Blepharisma has an adoral zone whose longitudinal orientation is characteristic of the more primitive heterotrichs. Moore (1924) claimed that no reorganization of remnants of an old adoral zone occurred in mutilated *B. undulans*. Depending on the degree of injury, either new elements were added directly at a cut surface, or after complete removal a new zone formed in the customary place. Since her comparative study of the holotrichous *Spathidium* (see above) had shown that regeneration in that form was always preceded by a dedifferentiation of an old mouth remnant, she concluded in this instance that ". . . no correlation is apparent between the degree of specialization of external organelles and the method of restitution" (p. 306). She also advanced the corollary that ". . . reversibility of organization is more limited in certain Protozoa than in others, but complexity of structure is not the controlling factor" (p. 307). One is inclined to question the validity of this conclusion from the available data, particularly in view of the cytological study by Calkins (1912). He found that dividing *B. undulans* replaced the parent adoral zone *in situ* at the anterolateral end of the body (cf. the site of the anlage in *Stentor*, etc.). Since there is a continuous functioning in the adoral zone throughout the division process, it seems only natural to consider the possibility that Moore failed to detect the gradual replacement of a portion of the old adoral zone in regeneration. In a different connection, Nadler (1929) tested the effects on *B. undulans* of certain chemicals, including strychnine sulphate; he

found that they caused shedding of the pellicle without affecting its subsequent regeneration upon return of normal conditions.

The complex, tunneled peristome of *Bursaria truncatella* provides favorable material for studies of regeneration. Lund's investigation (1917) revealed that the peristome is reorganized during fission and regeneration, being more completely dedifferentiated in the latter process. No nuclear changes were observed during these cytoplasmic phenomena. Lund likened the mechanism of dedifferentiation to the purely chemical process of autolysis; thus release of a proteolytic agent could be conceived to cause the breakdown of differentiated structures prior to their subsequent reorganization.

Hartmann's experiments on *Bursaria* proved inconclusive, since merozoa reacted to cutting by encystation. Sokoloff (1924) probed the general regenerative capacity of *B. truncatella* and found that relatively small nucleate merozoa (1/42 of body size) could reconstitute a complete organism. His data involving the reputed regenerative ability of enucleate fragments, however, were not convincing (cf. Prowazek, above). Schmähl's comparative study of division and regeneration (1926) corroborated the substance of Lund's work. Like Sokoloff, he noted a direct correlation between the size of a fragment and the time required for its regeneration. Reorganization never followed excisions that failed to injure the peristome or macronucleus; but where reorganization did occur Schmähl believed it probable that the entire ciliary coat also was replaced (which he had demonstrated in dividing forms). Joff (1923) investigated the rôle of mitochondria in regeneration. He discovered that rod-like bodies (demonstrated by Benda's technique) accumulated at the site of injury during regeneration; and the granular chromatin of the macronucleus became oriented in the same direction. Additional work would be welcomed to corroborate and extend his incomplete observations.

Licnophora is one of the most highly organized ciliates. Found only as commensals attached to various marine hosts, members of this genus are differentiated into a membrane-bearing basal disc, an erect oral disc with an adoral zone, and a supple intermediate region that serves as a neck. The nuclear apparatus includes a single basal micronucleus and a string of macronuclear beads. In her comparative cytological study, Stevens (1903b) included some regeneration experiments on *L. auerbachii*. Restoration occurred only when the basal disc, the neck, a small remnant of the oral disc and both kinds of nuclear material were present. Such regeneration included the new-formation of membranelles or of a new adoral zone and mouth, depending on the extent of removal, but no evidence was given of their formation by a differentiating anlage. Instead missing parts apparently were formed *in situ*. Isolated oral and basal discs never regenerated although they survived for several days.

Balamuth (1939) reinvestigated *Licnophora* with a view toward explaining this anomalous behavior. Protozoölogists had disagreed about its peritrichous and spirotrichous affinities since 1867. Study both of the structure and regenerative response of *L. macfarlandi* confirmed the view that this genus is a highly modified member of the Heterotrichina. Thus in contrast to Stevens' account, new oral membranelles were derived only from a migrating anlage which formed at the left anterior side of the body as in fission (Fig. 7). Its general regenerative capacity, moreover, was shown to be greater than formerly believed, since isolated,

amicronucleate oral discs definitely could regenerate injured adoral zones. This confirmed Schwartz's discovery for *Stentor* that the macronucleus alone is essential for new-formation of oral structures. Missing basal discs were not regenerated, but it was pointed out that the two daughter basal discs form in this genus only

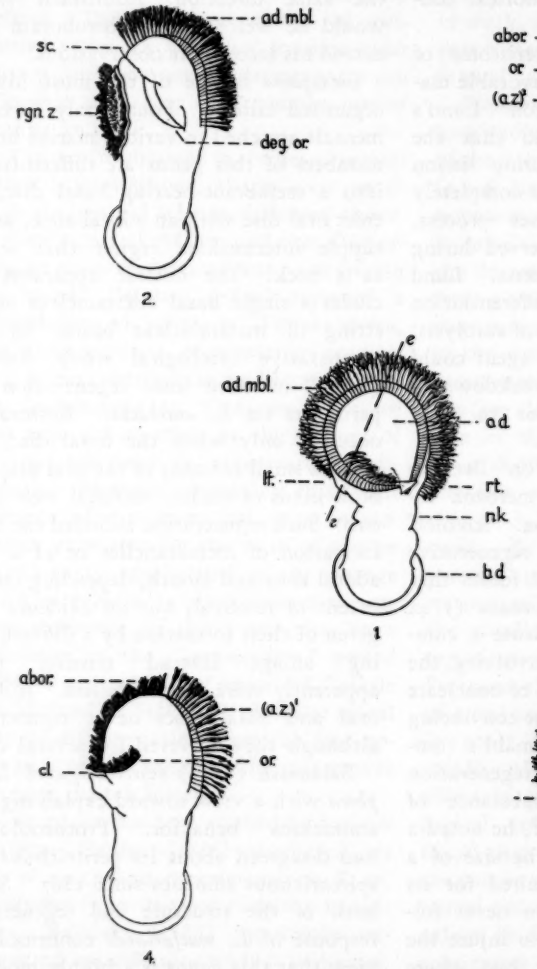

FIG. 7. REGENERATION IN LICNOPHORA MACFARLANDI FOLLOWING EXCISION OF THE LEFT SIDE OF THE ADORAL ZONE (DORSAL VIEW)

Some stages in the regeneration of an injured adoral zone, showing the establishment of a reorganization zone as in fission followed by its migration to replace most of the original zone. In its differentiation the new zone shifts from a dorsal to a ventral position. Nuclear changes are not shown in this figure, but are similar to those in *Stentor*. *e*.....*e* = line of excision; *abor.* = aboral end of new adoral zone; *ad. mbl.* = membranelles of adoral zone; $(a.z.)^1$ = original adoral zone; $(a.z.)^2$ = new adoral zone; *cl.* = lateral cleft; *or.* = oral end of new adoral zone; *rgn. z.* = reorganization zone; *sc.* = scar left by excision. (Original.)

by the constriction of a parent structure undergoing fission. If we adopt the view (as suggested by available data) that the regenerative capacity involves at most a realization of developmental potentialities, then the new findings for *Licnophora* become consistent with other data.

The Heterotrichina are clearly related to more primitive holotrichous forms. Even their adoral membranelles reveal a holotrichous ancestry, for these composite structures develop from groups of cilia in the stage of anlage differentiation. The Hypotrichina bear somewhat the same relation to the Heterotrichina. In these forms the primitive ventral ciliation (still retained in heterotrichs) is replaced by more specialized structures: cirri and membranelles. These localized organelles have enabled investigators to follow the process of regeneration in particularly great detail, and thereby to contribute some of the most important studies of experimental reorganization.

To Nussbaum (1884; 1886) belongs the credit for being the first to conduct systematic regeneration experiments on any Spirotrichida. Using *Gastrostyla* (?) *vorax* his limited data showed that only nucleate merozoa could regenerate: "It seems that the nucleus is indispensable for the maintenance of the formative energy of a cell" (p. 262).

The genus *Stylonychia* has proved favorable for experimental work. Dujardin's incidental opinion (1841) that mutilated *S. pustulata* could regenerate (see Section II, above) was corroborated by Prowazek (1898), who found that nuclear substance was necessary. The same author (1903b) referred to reorganization during "depression" in a related species, *S. mytilus*. He observed only some of the more obvious changes at the posterior end of the body. Dembowska (1925) used *S. mytilus* in her detailed comparison of fission (after Wallengren, 1901) with regeneration. She found a remarkably well-developed regenerative capacity, which included the complete reorganization of all somatic organelles whenever merotomy effected the removal of one or more of these. This restorative process was introduced at the left of the more anterior set of nuclei (except when only one set of nuclei was present in the merozoön) by the formation of an anlage containing in miniature a full complement of the 18 ventral cirri (Fig. 8, 1–3). Together with similar anlagen of a new adoral zone and of two rows of marginal cirri, these rudiments proceeded to migrate to their definitive positions; at the same time all old organelles were being resorbed at a proportionate rate (Fig. 8, 4–6). This restorative process closely simulated the reorganization accompanying fission. Having noted that only complete removal of a cirrus (including the basal plate) provided a sufficient stimulus for regeneration, Dembowska was led to conclude that regeneration in this species must be due to a disturbance in coördination of the locomotor organelles. Since the two kinds of nuclear material could not be separated, her observations on the rôle of the nuclear apparatus were limited to noting that regeneration occurred only in nucleate merozoa.

Young's study of the nuclear apparatus of *S. mytilus* during regeneration (1926) showed that the restoration of missing nuclei proceeded *pari passu* with cytoplasmic reorganization. He concluded that the nuclear complex has a constant species-character. Years previously Lewin (1911) had noted the tendency of micronuclei of *S. mytilus* to increase beyond the normal number during regeneration, while he apparently failed to see a reorganization zone; thus he stated, ". . . any reorganization . . . goes on by im-

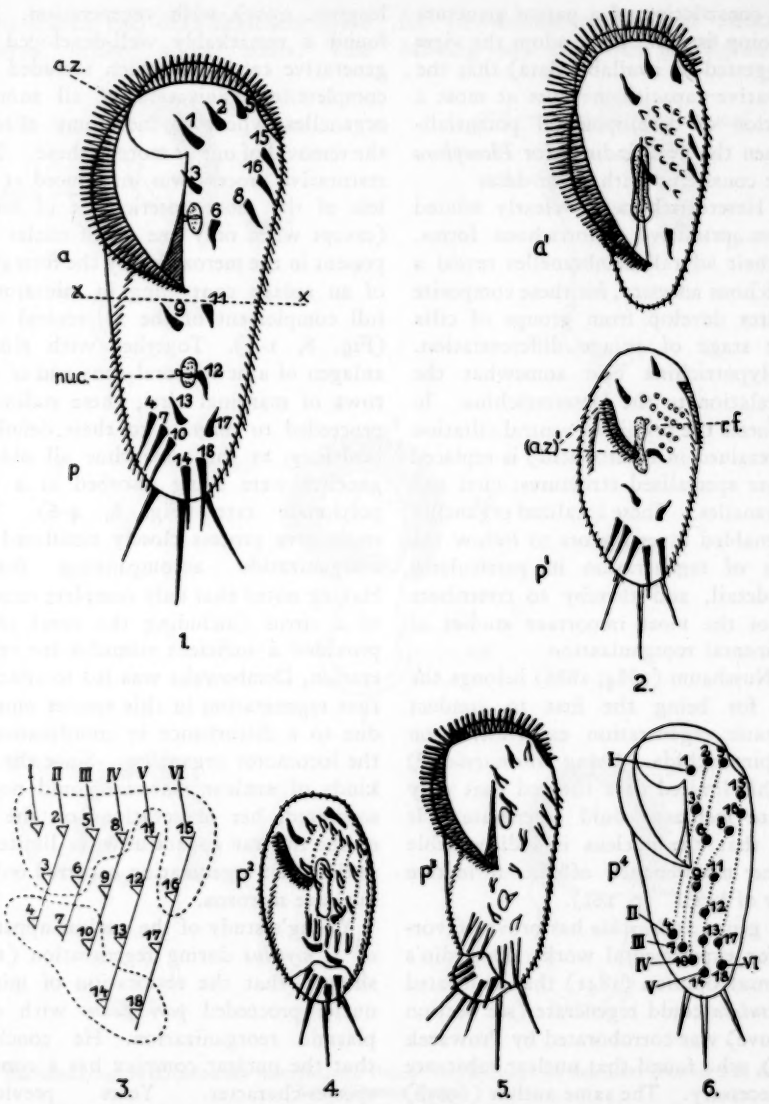

FIG. 8. STAGES IN THE REGENERATION OF A HYPOTRICHOUS CILIATE, STYLONYCHIA MYTILUS

1. Level of cut, showing two sets of nuclei. 2. Appearance of anlagen in reorganization fields of anterior $(a)^1$ and posterior $(p)^1$ merozoa. 3. Diagram of reorganization field, enlarged. 4–5. Stages in the migration of the anlagen to their definitive positions in a posterior merozoön (p^2-p^5). 6. Reorganized individual (p^6) showing path of migrating cirri. *x*.....*x* = plane of transection; *a.z.* = adoral zone; $(a.z.)^1$ = anlage of new adoral zone; *nuc.* = posterior macronucleus and micronucleus; *r.f.* = reorganization field. (After Dembowska, 1925, rearranged.)

perceptible stages." (p. 341). Hewitt (1914) had failed to confirm this nuclear behavior in *Pleurotricha* sp., but his data indicate that he may have neglected to examine regenerating individuals at a sufficiently advanced stage. Newer evidence from several ciliates has shown that there is often a multiplication of micronuclei during the regenerative process, but apparently the normal number is restored before the next fission. Tittler (1938), for example, produced merozoa of *Uroleptus mobilis* by the disintegrative action of induced electric currents, as Verworn (1889) previously had done for many Protozoa. He noted that the micronuclei of regenerating fragments often multiplied beyond the normal number, but the extra ones apparently were resorbed before division occurred. It should be noted in this connection that no investigator ever has confirmed Le Dantec's poorly supported opinion (1897) that micronuclei could be reconstructed from macronuclear substance. His material included several unnamed ciliates, each *presumably* containing only one micronucleus, which he cut into two macronuclear fragments. The subsequent finding of a micronucleus in each merozoön led him to conclude that ". . . in certain cases at least, the micronucleus is regenerated in merozoa not containing any trace of the old." (p. 51).

Dembowska (1926) compared the regenerative capacity of several other hypotrichs with that of *Stylonychia*. *Diophrys* sp. responded equally well to merotomy, even small nucleate pieces regenerating completely. In so far as some unsystematic experiments on *Amphisia* (?) sp. and *Actinotricha* sp. permitted a conclusion, they seemed to react similarly to *Stylonychia*.

Euplotes has been studied in many connections, some of which have contributed data to the problem of regeneration. Taylor (1920) made incidental references to regeneration in his cutting experiments on the fibrillar system of *E. patella*. Taylor (1923) and Taylor and Farber (1924) removed the micronucleus from *E. patella*, using a micro-pipette. Such amicronucleate individuals evidently suffered from a waning vitality, since all experimentals (50) died within a few days without dividing more than twice. Regarding the rôle to be ascribed to the micronucleus in cellular activity, Taylor and Farber indicated that ". . . the conclusion is inevitable that the micronucleus possesses more than a germinal function in the life of this organism" (p. 139).

Dembowska's experiments on *E. charon* and *E. vannus* (1926) simply confirmed the essential points of her above work. Compared to other forms, regeneration in *Euplotes* was noticeably slower. Reynolds (1932) used *E. patella* for cutting experiments. She noted a definite racial variation; thus in one race tentatively identified as *E. patella*, operated individuals regularly disintegrated soon after cutting, while in a second race regeneration occurred only in anterior merozoa containing the micronucleus, part of the macronucleus and sufficient cytoplasm. Amicronucleate individuals always died, regardless of their size.

The same work of Reynolds (1932) included data on *Oxytricha fallax*. This species proved especially interesting, since she used normal and amicronucleate races. The normal, micronucleate race responded like the closely related *Stylonychia* (see above). All the regenerating merozoa contained both macronuclear and micronuclear substance. In the amicronucleate race, however, viable merozoa contained only macronuclear substance, and these too regenerated completely. Reynolds was drawn to the conclusion

that the nuclear content of normal, amicronucleate individuals differed from that of amicronucleate individuals produced experimentally. This might be explained by adopting Woodruff's view that the "macronucleus" of amicronucleate ciliates actually may be an amphinucleus; thus both nuclear elements would be included within a common mass functioning in a dual trophic and germinal capacity.

Calkins (1911a) made the interesting discovery in *Uronychia transfuga* that the regenerative capacity is a function of the interdivisional age. During regeneration the adoral zone and powerfully developed cirri of this complex form were completely reorganized, in the manner described for fission by Wallengren (1901). Cuts made at spaced intervals between division periods separated two kinds of fragments; both contained part of the elongate macronucleus, but only one (depending on the kind of cut) contained the small micronucleus. Of those individuals cut soon after division (up to one hour), only merozoa containing both nuclear elements regenerated, but even these varied in their capacity. In older individuals (about halfway between division periods), the regenerative capacity proved considerably better; not only did merozoa containing both nuclei regenerate, but also amicronucleate fragments were reorganized normally so long as macronuclear substance was present. Thus the regenerative capacity was indicated to be greatest at an advanced interdivisional age, when only the macronucleus was necessary for complete regeneration. Conversely this capacity became reduced immediately after division. The inference was that something not present in the cytoplasm of a newly divided individual became replenished under nuclear influence as maturity was reached.

Young's study of *U. setigera* (1922) fully corroborated Calkins' findings. He noted that regeneration did not follow the cutting of cirri so long as their basal plates were not injured; this pointed again to disturbance in coördination of locomotor organelles as a possible impulse to regeneration. Young strengthened Calkins' results still further by showing for *U. binucleata* that regular regeneration both of anterior and posterior merozoa was correlated with the normal presence of a micronucleus in each part of the body (hence *binucleata*). He concluded that although regeneration definitely occurs at times without the micronucleus, "The ability to grow and divide is dependent on the presence of a micronucleus" (p. 388).

The Hypotrichina display great variation in the place of origin of reorganization zones during asexual reproduction. In *Stylonychia* two distinct reorganization fields appear, one anteriorly and one posteriorly. In *Uronychia* one "compound" field suffices for both daughter individuals. *Diophrys* discloses an additional variation, in that two reorganization fields arise close together posteriorly. Indeed, the one permissible generalization rests in the essential similarity between the course of fission and of regeneration in a given genus. Dembowska's comparative study of *U. transfuga* and *U. setigera* (1926) emphasized once again this general similarity.

Taylor's thorough study of *U. uncinata* (1928) corroborated the essential points in previous work. Taylor presented an interesting theory of protoplasmic reorganization, emphasizing the similarities between normal, cyclical reorganization and the course of regeneration. According to this theory, all protoplasmic reorganization would involve essentially a dispersion (dedifferentiation) followed by

a recondensation (redifferentiation) of the molecular components of cellular structures. Accompanying this profound resynthesis there might well occur a "physiological rejuvenescence" in the sense of Child. Consequently, the effect of reorganization in general can be visualized in terms of a heightened physiological activity. A favorable feature of this hypothesis is that it is susceptible to a precise experimental approach; also it takes cognizance of an underlying similarity between fission and regeneration.

It is obviously desirable to correlate morphological and physiological data in seeking evidence of "rejuvenescence," "aging," etc. Bauer and Granowskaja (1934a and b) have made a pioneer attempt in this direction for Protozoa, using *Oxytricha* sp. and *Gastrostyla* sp. It is interesting to compare their theory of protoplasmic reorganization with that proposed by Taylor. Their starting-point is a thermodynamic concept of the cause of rejuvenescence. Briefly, it postulates that the onset of cellular reorganization is dependent upon attaining a "growth-limit." The latter is restricted in turn by the amount of free energy per unit mass available for further assimilation, and growth will cease when the mean free energy begins to decrease. In order to restore the potentiality for further growth, a decrease in the biological system (*i.e.*, cell division) must occur and liberate additional energy. In other words, normal reorganization (cell division) will occur only when the capacity for further assimilation reaches a certain limiting threshold. At this point cell division ordinarily serves the dual function of diminishing the biological mass and, in some unknown manner, of liberating additional energy to be used in further growth. The advantage of this theory is to provide a cause for reorganization and to show how the end-result satisfies the impelling cause. To apply this theory to protozoan regeneration, they argued as follows: Since the immediate impulse to rejuvenescence apparently is a natural decrease of mass, experimental removal of part of the body (merotomy) might be able to replace fission as a rejuvenating stimulus.

Their first paper (1934a) sought to discover whether the nuclear changes and respiratory rate of operated individuals indicated that a rejuvenating process was actually at work. On the whole, the results supported their hypothesis. Thus they showed that adult and young individuals reacted differently to merotomy; only the former (*i.e.*, individuals having reached the "growth-limit") showed evidences of experimental rejuvenescence. These underwent a complete macronuclear reconstruction that was accompanied by an intensified respiratory rate (measured by a Kalmus respirometer). Young individuals, on the other hand, did not undergo nuclear reconstruction, but instead exhibited a lower respiratory rate.

In their second paper (1934b), these investigators used a different approach. Hartmann had claimed that repeated regeneration could be substituted indefinitely for fission, as a result of experimenting on *Stentor coeruleus* (1922) and on two species of *Amoeba* (1924; 1928; also see *Sarcodina*, above). Bauer and Granowskaja showed that this held true only when the age factor discovered above was recognized. Consecutive operations on individuals which had reached their maximum size resulted each time in complete reorganization, and hence raised the possibility of the indefinite existence of a protozoön as one undivided individual. Their most successful experimental was still alive after 28 days (cf. 52 days for *S. coeruleus* and 4 months for *A. proteus* in

Hartmann's experiments). Repeated operations on young individuals resulted inevitably in their death. Bauer and Granowskaja concluded that experimental "individual immortality" (Hartmann) is the result of the same physiological reconstruction processes which occur at periods of division. Merotomy apparently disturbs the fission normally associated with these processes and substitutes instead the regeneration of the original system.

These data may aid in explaining the previously recorded behavior of *Uronychia* and *Oxytricha*. In both these forms only adult merozoa could regenerate consistently, while younger stages usually failed to do so, especially in the amicronucleate condition. The work of the Russian investigators indicates that younger stages of some Hypotrichina may be quite different in their general physiological potentialities from later periods, as indicated, for example, by a different respiratory rate and morphologically expressed nuclear inactivity. A slighter capacity to regenerate may be one expression of this difference. Future investigations should be designed to corroborate these data and test the possibility of extending this approach to other phases of cellular activity.

In concluding this account of the Holotrichida and Spirotrichida, it seems clear that an increasing order of complexity is accompanied by a more regular pattern of regeneration. The well-defined anlage of the adoral zone of heterotrichs is succeeded in hypotrichs by localized anlagen for nearly all ciliary organelles. Now, it happens that recent anatomical studies of even the least specialized ciliates, the holotrichs, indicate that a precise cytoplasmic mechanism equivalent to anlage formation also operates in those forms, at least during fission. Chatton and his collaborators have established in various genera undergoing fission that the newly forming mouth regions are in genetic continuity with the parental structure. This is caused by the proliferation of new basal granules and connecting fibrils either from a central primary stomatogenous fibril (*cinétie stomatogène*) or from a more diffuse ciliary field, the details varying.

It is instructive in this connection to turn to the one group of ciliates still to be treated here, the Peritrichida. The structure of these forms indicates a derivation from generalized holotrichs. This derivation is emphasized by the existence in this group also of a genetic continuity of oral structures (Chatton and Villeneuve, 1937). Indeed, the authors state: "The Peritrichida exhibit . . . the most direct kind of genetic continuity of oral structures that is known to us." Experimental corroboration of these anatomical accounts may be anticipated in the near future.

The Peritrichida have been subjected to few experiments. The most fruitful approach has been used by Summers (1938a and b), on a complex colonial type, *Zoothamnium alternans*. The frond-like shape of this species results from the geometric precision with which its colonial members differentiate. The apical cell (terminal macrozoöid) acts as a growing-point, and on each side gives off branches alternately which proliferate laterally. Six types of individuals are produced during the growth cycle of this species. Summers tested the ability of colonies to regenerate following the removal of various parts. The regenerative capacity proved to be well-developed. Thus removal of the terminal macrozoöid generally resulted in the assumption of that dominant position by the next lower terminal branch zoöid, although in some

instances other individuals became the new growing-point instead. The inference was that removal of the terminal macrozoöid disturbed the physiologically dominant region of the colony, so that adjustments were necessary to establish a new relation of dominance-subordination. The consequent shift in morphogenetic expression indicated the labile and reversible nature of the colonial organization. On the whole, regulatory responses were evoked more readily in the younger individuals of the colony.

Summers suggested that time might play an important rôle in determining the reactivity of the different cells, for it was known that protozoan cytoplasm undergoes progressive physiological changes between division periods. Thus "... the intracellular activities of a *Zoothamnium* cell may lead to the "fixation" of specific potencies at some critical period after cell division ..." (p. 148). The expression of physiological dominance is also clearly important under normal conditions, since the transformation of the terminal macrozoöid into a conjugating macrogamont results in the temporary shift of dominant growth to a subadjacent point. *Zoothamnium* presents good evidence, therefore, that regulatory mechanisms exist normally as in some Metazoa, and may act according to the degree of determination of certain cells.

The important rôle of physiological dominance in peritrichs was noted as early as 1914, by Runyan and Torrey. When a solitary vorticellid (*e.g.*, *Vorticella* sp.) undergoes fission, the migratory daughter individual develops an aboral ciliary ring soon after losing contact with the parent stalk. By removing normal individuals from their stalks, they experimentally induced the same response. The presence of a stalk, therefore, apparently inhibits the appearance of aboral cilia.

The relation of physiological dominance and subordination of parts has been disclosed in a series of studies on protozoan regeneration. For example, the onset of regeneration seems to vary inversely with the extent of injury. Thus Morgan (1901b) found that the presence of a portion of the old peristome of *Stentor* inhibited the formation of a new one. Similar observations have been recorded by Moore (1924) for *Spathidium;* by Dembowska (1925) for *Stylonychia;* and by Schmähl (1926), Taylor (1928), etc. Since Child's demonstration (1914) of a metabolic gradient along the anteroposterior axis of ciliates, other investigators have confirmed the fact that the anterior region of the body generally occupies a dominant position. Taylor (1928) and Tittler (1938) have found that anterior merozoa begin to regenerate sooner than posterior merozoa. This might explain Dembowska's observation (1925) that the regenerating anlagen in *Stylonychia* always made their appearance alongside the anterior nuclear complex when it was present. Future study must decide whether the determining factor in such instances is a higher metabolic activity anteriorly.

The only ciliates remaining to be considered are a few endoparasitic forms which have received little attention. Sokoloff (1924) found that *Anoplophrya filum*, a large astomatous holotrich, had a very slight regenerative capacity posteriorly; thus replacement of cilia proved more successful at that end of the body. The opalinid ciliates respond poorly to all experimental treatment since they cannot be cultured successfully outside their amphibian hosts. Nussbaum (1884; 1886) found that fragments of *Opalina ranarum* disintegrated after a few hours without

showing evidence of recovery. Sokoloff (1924) used various salt concentrations in his culture media, but *O. ranarum* never survived longer than 12 hours. He reported the appearance of some cilia at a cut surface, but this irregular response was the only indication of regeneration. In Joff's study of *O. ranarum* (1923), it was shown that rod-like bodies (mitochondria) accumulated at the edge of a wound within an hour after cutting, but he gave no evidence of regeneration. It would seem, therefore, that endoparasitic ciliates do not react like free-living forms. Since satisfactory nutritive media were not provided in these experiments, however, final judgment must still be withheld.

(2). *Regeneration in dividing individuals*

We have seen that ciliates in ordinary vegetative stages possess a remarkable ability to restore missing parts. The question arises, whether or not the regenerative capacity is equally well-developed during other stages of the life cycle, that is, during fission, encystment and conjugation.

Only a few of the many references to merotomy during fission have disclosed important facts. Gruber's few data (1885b) indicated that *Stentor* undergoing fission had the same regenerative capacity as at other times. The work of both Peebles (1912) and Tartar (1939) on *Paramecium caudatum* supported this view. On the other hand, Calkins' study of *Uronychia* (1911a) showed that late division stages reacted relatively poorly to cutting. Where cytoplasmic viscosity decreases during fission, recovery may become more difficult in proportion to the greater danger of diffluence.

There is evidence that a "division zone" is established in ciliates even before the appearance of external signs of fission. This would explain the fact, first mentioned by Balbiani (1892), that merotomy often does not interrupt the physical cleavage process and may result, therefore, in the production of unequal sized offspring. Fauré-Fremiet's study of *Urostyla grandis* (1910), a large hypotrich, showed that division is a reversible process up to a certain stage. During the earlier period, operated individuals returned to the vegetative condition and regenerated before dividing. Merotomy during the later stages showed that division had become irreversible. The behavior of dividing *Stylonychia* discloses some additional facts. Dembowska (1925) found that merotomy had no effect on the division process, since this continued in all instances studied. Concerning regeneration, she found that removal of parental organelles (organelles destined to be replaced during fission) did not cause a regenerative process to follow division. The excision of any newly forming organelles, however, resulted later in the regeneration of all organelles in the "presumptive" offspring which had been mutilated.

The irreversible nature of the division process leads logically to the problem of whether or not morphogenesis itself can become irreversible during fission. If that should occur, then one might expect new-formation to occur in enucleate dividing merozoa. Gruber (1885b) reported that this actually was the case in amacronucleate dividing *Stentor*, stating ". . . we are dealing with a movement whose course no longer can be halted, even if the moving force (*i.e.*, the macronucleus) is removed" (p. 140). Stevens (1903a) extended this observation to regenerating individuals, in which an anlage had appeared before she removed the "balled" macronucleus. Balbiani's work (1892) on *Stentor* cast some doubt

on these data, since he showed that new-formation could continue in enucleate dividing merozoa only in late stages ("balling" of the macronucleus); when the macronucleus was removed in earlier stages the anlage did not continue to develop. The interpretation to be derived from this fact is that nuclear material seems to be essential to the formation and maintenance of an anlage until a certain irreversible stage is reached. Following that stage, further development probably involves essentially the unfolding of structures already present as rudiments.

(3). *Regeneration in encysting individuals*

Encystment occurs at various times in ciliates, in some for protective purposes, in others for endomictic reorganization, and in a few forms during the division process. Where the last occurs (*Stylonethes*, *Colpoda*, etc.), it should prove interesting to learn whether the mode of regeneration is in any way correlated with this. An incidental observation by Garnjobst (1937) did show that *Stylonethes sterkii* regenerated within a cyst after accidental injury. Apparently the same fundamental processes underlie both division and regeneration in this form also.

(4). *Regeneration in conjugating individuals*

The reorganization of the nuclear apparatus during conjugation raises the question, whether or not changes occur also in regenerative capacity during this period. Balbiani (1892) noted that the ability to regenerate varied with the stage of conjugation. When cut soon after joining in conjugation, *Stentor* regenerated consistently. The nuclear apparatus of these individuals had not begun to reorganize. Later, when the old macronucleus had begun to be resorbed, regeneration did not occur after merotomy. Toward the end of the conjugation process, after the appearance of the new macronuclear anlagen, cutting again evoked the regenerative response. As indicated in the section on *Ciliata* (see above), this furnished indirect evidence of the importance of the macronucleus during regeneration. Calkins (1921) operated on *Uroleptus mobilis* during various stages of conjugation. He showed that removal of the cytoplasmic bridge containing the migrating gametic nuclei had no effect on the reorganization process. Once under way, nuclear and cytoplasmic reorganization continued in the merozoa without cross-fertilization. Operations on individuals preparing to conjugate, however, were not followed by any similar nuclear reorganization. As in fission, therefore, there seems to be an early stage of labile determination, following which the conjugation process becomes irreversible without regard to the consequences.

(b). Physiological regeneration

All the preceding accounts of regeneration have had at least one element in common, namely, a restoration of structures caused by some kind of injury to the body. Physiological regeneration, on the other hand, involves a process of replacement whose immediate cause may not be noticeable, but which is traced to a *normal growth process*. Periodic moulting and replacement of worn-out parts fit into this category; and the apparently spontaneous replacement of the oral region of ciliates has also been ascribed to this process. However, the dividing line between physiological regeneration and restorative regeneration in Protozoa cannot be very sharp. The partial fusion of two bodies during conjugation, for example, causes the local resorption of organelles. Maupas (1889) described the ensuing fundamental reorganization of all somatic organelles in several genera of the Hypo-

trichina; Hammond (1937) recently analyzed *Euplotes patella* with particular care. In all reports the reconstitution has been found to simulate the course of experimental restoration.

Are these instances of restorative regeneration or physiological regeneration? The latter presumably results from the operation of a normal internal mechanism, and yet conjugation can be induced experimentally. Many investigators have supported the view that conjugation induces nuclear and cytoplasmic rejuvenescence. If this is true, then the reorganization of somatic organelles involves their "physiological regeneration." A different view is available, however. Maupas (1889) regarded the cytoplasmic reorganization accompanying conjugation as essentially a kind of restorative regeneration, made necessary by the lesions resulting from the physical act of mating. The available evidence seems to favor this latter view as the more reasonable one.

The classical example of physiological regeneration in ciliates is the spontaneous replacement of the adoral zone in free-swimming *Stentor*. Balbiani (1891a) described the process in *S. coeruleus* (Fig. 9), and showed that the nuclear and cytoplasmic aspects of reorganization were similar to those occurring in fission (*cf.* Fig. 6). He discovered also that cultural conditions could exercise some effect: ". . . by placing these animals under certain cultural conditions, . . . after some days there are induced numerous regenerations, the course of which occurs in a perfectly regular manner" (p. 324).

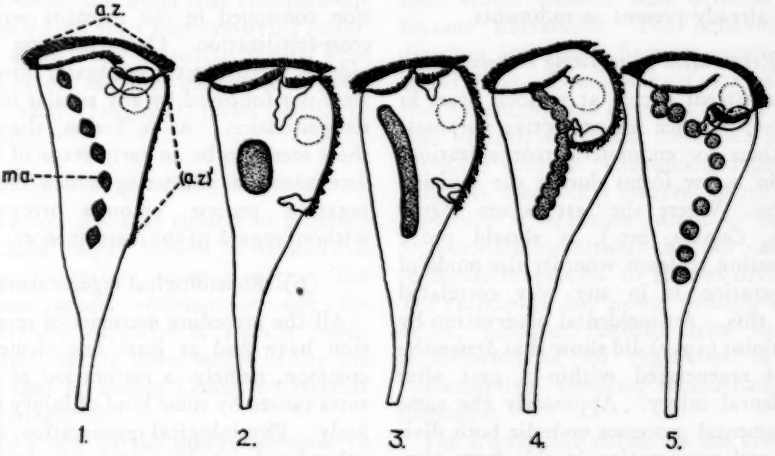

FIG. 9. PHYSIOLOGICAL REGENERATION IN STENTOR COERULEUS, SHOWING PROGRESSIVE REORGANIZATION OF THE ADORAL ZONE AND MACRONUCLEUS (CF. FIG. 6)

a.z. = parental adoral zone; $(a.z.)^1$ = anlage of new adoral zone; *ma.* = macronucleus. (After Schwartz, 1935, redrawn and slightly modified.)

Physiological regeneration has been recorded for other Protozoa. Johnson (1893) independently confirmed Balbiani's account, using *S. coeruleus* and *S. polymorphus*. Fauré-Fremiet (1906) described in detail an abnormal individual ("monster") of *S. coeruleus*, which apparently resulted from abortive physiological regeneration. Schwartz (1934; 1935) described the process in this species most recently. He supported Balbiani's opin-

ion that it represented a normal, periodic growth process.

Other ciliates in which physiological regeneration has been described include *Nassula* (mentioned by Chatton and Lwoff, 1936); *Colpidium campylum* (Klein, 1928); *Glaucoma scintillans* (Chatton, Lwoff, Lwoff and Monod, 1931; von Gelei, 1935); *Bursaria truncatella* (Lund, 1917; Schmähl, 1926); *Licnophora macfarlandi* (Balamuth); *Holosticha rubra* (Wallengren, 1901); and *Cyathodinium piriforme* (Lucas, 1932). *Cyathodinium* is especially interesting because of its unique mode of reorganization; the new ciliature and peristome arise as an intracellular anlage which later migrates to the surface. It is notable that the same kind of reorganization process occurs during fission.

Physiological regeneration has been recorded also in other groups. Cienkowski (1873) noted in *Noctiluca* that "... the flagellum is often gradually resorbed and then regenerated on the rounded-up body" (p. 50). The heliozoan, *Wagnerella borealis*, regularly replaced its capitate upper end after losing it spontaneously (Zülzer, 1909). An equivalent process of restoration has been described even in the parasitic Sporozoa. Léger and Duboscq (1904) found that the gregarines, *Stylorhynchus* and *Pyxinia*, could spontaneously regenerate attachment-organelles (epimerites), depending on the trophic conditions.

Finally, attention should be drawn to an investigation by Hetherington (1932). He questioned whether physiological regeneration was a "*normal growth process*" in *S. coeruleus*, since he could find no evidence of its occurrence in controlled culture media. In mass cultures, on the other hand, such reorganization occurred frequently. His conclusion was simply that chemical as well as physical stimuli can induce regeneration. The inference seems clear that what has been termed "physiological regeneration" may also be a reparative process. This would remove it from its status in a special category.

(5). *Influence of environmental factors on regeneration*

Environmental conditions exert a definite influence on the course of regeneration. For example, growth processes generally vary directly with the temperature within the biological range. Morgan (1901b) was able to inhibit the regeneration of *S. coeruleus* for many hours by subjecting merozoa to low temperatures. Later investigators have amplified the general applicability of this fact.

It is well known that the hydrogen-ion concentration sets definite limits to growth capacities and even to viability. Sokoloff (1924) noted that ciliates responded very differently to changes in acidity; thus *Dileptus* regenerated at a pH of 9.2 with little difficulty, while fragments of *Bursaria* did not remain viable at a pH above 8. Chejfec (1932) attempted to increase the regenerative capacity of *Paramecium* by varying the hydrogen-ion concentration. He found that the ciliates survived and regulated better in a more acid medium (pH of 5). Since the viscosity of cytoplasm increases at a lower pH, apparently this is an important factor in accounting for the difference. Tartar has observed that *Paramecium* can be cut more easily in an acidified medium, owing to the changed physical condition of the outer cell-layer.

The effect of the ionic composition of the medium on the regenerative process has not been studied sufficiently. Balbiani's preliminary work (terminated by death) in 1899 showed that a hypertonic solution could have the same effect as merotomy. When *Stylonychia mytilus* was

subjected to a 0.25 per cent solution of "sea salt," various parts of the body underwent gradual dissolution. These mutilations proved readily reversible upon return to normal conditions, although Balbiani failed to detect evidence of an anlage during regeneration. Sokoloff (1924) tested the relative effects of different ions on regeneration. Using several ciliates, he found that in weak concentrations mixtures of Na and Ca ions exercised a stimulating effect on healing and regulation of shape, the Ca ions being most beneficial of those used. This is possibly related to the mechanism in metazoan cells, for Heilbrunn (1934) and others have shown that the Ca ion acts in membrane formation following merotomy (the surface precipitation reaction). Further experimentation along these lines is definitely necessary.

The nutritive condition seems to play an important rôle in reorganization. Wallengren's analysis of *Paramecium caudatum* (1902) showed that inanition induced a series of progressive changes in the cytoplasm and macronucleus. These included resorption of cilia, vacuolization of the endoplasm, structural alteration and fragmentation of the macronucleus. Such changes were reversible up to the point where prolonged starvation finally caused granular degeneration of the cytoplasm. It may be concluded, therefore, that starvation finally produces an irreversible change in cytoplasm that is not comparable to the effect of earlier stages of inanition. Enriques (1912) compared the effects of hunger and "senile degeneration" on the nuclear apparatus of two hypotrichs, *Opercularia coarctata* and *Stylonychia pustulata*. He found that the macronucleus experienced similar changes in both instances, agreeing with Wallengren's description. These degenerative modifications during hunger were used as evidence of a visible disturbance in the normal secretory activity of the macronucleus. Lund (1917) noted that starvation caused *Bursaria* to decrease in size from 600μ to less than 90μ. Reorganization of these smaller individuals often occurred after two or three days without food. Evidently inanition induces deep-seated changes in protozoan organization.

Several studies of regeneration already referred to have included data involving nutritional factors. Peebles (1912) showed that starvation of *Paramecium* caused a decrease in regenerative capacity. Similar results were obtained by Young (1922) on *Uronychia*, and by Moore (1924) on *Spathidium*. Using *Bursaria*, Sokoloff (1924) found that individuals which had been deprived of food for two days regenerated better than the average, while more advanced deprivation caused the loss of all regenerative ability. Chejfec's study of *Paramecium* (1932) supported Sokoloff's results in showing that mild hunger increased the incidence of recovery and regulation of merozoa. These results agree, in general, with the implications of Wallengren's study.

In this connection the recent work of Dembowska (1938) is especially timely. Having observed that *Stylonychia mytilus* occasionally underwent a complete reorganization without apparent cause, Dembowska investigated the rôle of cultural conditions. She was able to demonstrate that hunger was the causal factor, acting probably through an altered structural organization. Thus by withholding all food during the lifetime of an individual, it underwent a series of repeated reorganization processes quite similar to those occurring in fission and regeneration (*cf.* Fig. 8). The average response was 26 complete reorganizations during a 19-day period of viability. Reorganization occurred more frequently with advancing

hunger, so that toward the end the ciliates were literally in a condition of permanent reorganization. Both types of nuclei tended to multiply as in fission, but the extra ones were resorbed in each instance before the following reorganization process.

This investigation may account for several reports of apparently spontaneous reorganization which have been referred to the special category of physiological regeneration. It may hold in some of these cases that instead of a periodic growth process, simple environmental factors have acted as causal stimuli. It will be recalled that Balbiani (1891a), Lund (1917) and Hetherington (1932) also noted an effect by the milieu on the onset of "physiological regeneration."

Among environmental factors not usually considered is that of parasitism. Many Protozoa are attacked by parasites, although the true nature of these invaders was not established until after the middle of the nineteenth century. As early as 1876 Bütschli made some interesting observations on parasites of ciliates. In several instances he was able to transfer infections of suctorians from ciliate to ciliate. More to the point, he recorded the complete reorganization of the peristomal region in a *Stentor coeruleus* which had been parasitized by a holotrich (p. 349). It is possible that some injurious action of the parasite provided the necessary stimulus for reconstitution. Most of the records of parasitism in Protozoa simply describe progressive degeneration of the hosts.

To summarize this phase of the review, it seems that regenerative processes can be induced by other factors besides merotomy. Certain environmental stimuli evoke a reorganization comparable to that following physical removal of material. The response always seems to follow a fundamental course which is roughly analogous to the mechanics of fission. No proof has been offered to show that physiological regeneration does not exist, but in the light of recently exposed facts a reinvestigation of previous reports and further, controlled experiments seem highly desirable.

IV. EVIDENCE BEARING ON THE MECHANISM INVOLVED IN REGENERATION

The descriptive aspects of regeneration have an intrinsic interest, but they leave unsolved the more fundamental problem, namely, the nature of the *mechanism* underlying these remarkable form-changes. In each instance the course of morphogenesis is determined by the degree of organization of given Protozoa. Functional necessities have been met by a wide variety of structural adaptations. In some forms, indeed, there is even a progression of cyclical stages involving complicated metamorphoses (cf. the malarial parasite, or Foraminifera, or certain ciliates). Although this complex organization is contained within a common limiting membrane, it is unsatisfactory to regard a protozoön as equivalent to a metazoan cell. The true point of comparison rests in the organismal nature both of Protozoa and Metazoa. As long ago as 1852 Perty indicated the inadequacy of the *cellular* approach in concluding that ". . . this *Concept of the Cell* in no way has universal validity; in the lower creatures the organism and the cell (or cells) are identical" (p. 51). In this century Dobell (1911) and others have elaborated upon this thesis of the non-cellularity of Protozoa.

If we regard the Metazoa and Protozoa as comparable groups, then morphogenetic changes during the development of multicellular forms should be reflected by some analogous ontogenetic processes in Pro-

tozoa. Facts already presented support this view. A protozoan individual develops during fission from a relatively homogeneous substratum. Progressive cytoplasmic and nuclear changes occur between reproductive periods; and regenerative potencies, for example, depend on the physiological condition at a given moment. In other words, just as formative processes transform a germ cell into a mature metazoan individual, certain comparable processes act on a developing protozoön. All the available evidence has indicated that the regenerative process follows the same general course as fission. The inference is that regeneration too is essentially a kind of development. Preservation of species-identity emerges as the fundamental problem. Apparently the causal mechanism of reorganization may be stimulated in various ways. Under ordinary circumstances it consists in growth beyond the normal limit; under experimental conditions of regeneration it may include any of a number of physical and chemical disturbances.

The formative process must receive its initial impulse either from the cytoplasm or the nucleus, or possibly from an intimate interaction of the two. Most investigators have been concerned more with the *mechanics* than with the *mechanism* of regeneration, and accordingly have emphasized the more obvious cytoplasmic phases of reorganization. It has been shown, however, that nuclear changes also definitely occur. Some workers have supported the opinion that the cytoplasm is the seat of the formative mechanism, despite the fact that enucleate fragments invariably fail to survive the effects of merotomy. Loeb (1899) reflected one approach used by this group in offering the opinion that ". . . the nucleus is the oxidative organ of the living substance; . . . enucleate cell-fragments are unable to regenerate only because in them the oxidative activities have sunk to a subminimal level" (p. 692). This view would reduce the nucleus to the rank of an essential but subordinate organelle. Loeb was apparently unaware of the fact that Verworn (1892) had shown that enucleate fragments of *Bursaria* also utilized oxygen. Lynch (1919) presented even more effective evidence against Loeb's hypothesis, using *Amoeba proteus*. His data demonstrated that repiration and metabolic rate are not depressed by enucleation. He argued, therefore, that there must be important centers for oxidation in the cytoplasm.

Others, such as Prowazek (1913) and Sokoloff (1924), have supported Loeb's view, consciously or not, in claiming that the nucleus is not always essential for regeneration. As recently as 1929 Klein claimed that the ectoplasm and silver-line system of ciliates represent the site of formative energy. With no direct evidence of his own for support, he asserted: "During regeneration the nucleus remains completely inactive and does not participate in the restorative process" (p. 251).

Evidence favoring the nucleus as the source of regenerative energy has been more abundant, and is derived from various channels. Morphological evidence from fission indicates that nuclear activity often precedes the first cytoplasmic changes. Evidence involving ciliates should prove especially valuable, since trophochromatin and idiochromatin are considered to be segregated in these forms. Summers (1935), Hammond (1937), Young (1939), etc. have shown that macronuclear reorganization begins before cytoplasmic changes in various Spirotrichida. Awerinzew (1936) described the interesting changes accompanying fission in *Lagenophrys*, a stalked peritrich. Besides noting the above, he observed that the macronucleus of the

migratory daughter individual alone acquired an irregular shape and gave off fragments to the cytoplasm. These evidences of activity were correlated with the fact that only the migratory daughter formed a new attachment apparatus and test. Extrusion of chromatin elements during macronuclear reorganization has been reported in many other ciliates. Although its significance is not yet clear, from a chemical point of view it is plain that this "purification process" (Calkins, 1930) must liberate complex substances into the cytoplasm. In this site they would be available for further use. Another indirect evidence of nuclear activity during morphogenesis is the reference by Bütschli and others to the accumulation of nuclei at the site of shell secretion in Foraminifera (see *Sarcodina*, above). Physiological evidence also indicates that the nucleus (macronucleus in ciliates) is a site of secretory activity. Thus enucleation impairs the healing of cut surfaces, the secretion of sticky substances by locomoting amebae, the digestive function and all anabolic processes.

Regeneration experiments have contributed more direct evidence of nuclear activity during morphogenesis. Early work by Brandt (1877) on *Actinosphaerium* and by Schmitz (1879) on unicellular algae (*Valonia*, etc.) had shown that the nucleus must be present for new-formation. This had provoked the long series of experiments by Nussbaum, Gruber and others on Protozoa. Regeneration is clearly dependent upon the presence of nuclear substance in these organisms. In the ciliates, furthermore, it has been shown that the macronucleus alone controls the onset and maintenance of regeneration (see *Ciliata*, above). Certain facts derived from occasionally abnormal regeneration also have supported these findings. Balbiani (1891b) produced a "double monster" in *Stentor coeruleus* by incomplete merotomy. He correlated the dual cytoplasmic organization with the dual macronucleus which was also present. When the two sets of macronuclear segments fused to form a single macronucleus, there resulted a striking cytoplasmic rearrangement and the restoration of a unitary organization. Macronuclear activity seems to have been the guiding factor. There are many other instances of monster-formation in Protozoa as a result of abnormal regeneration, but the behavior of the nuclear apparatus has not been followed closely. Rhumbler (1902) distinguished between "multiple-individuals" and "cleft-individuals" in his analysis of foraminiferan monsters. Calkins (1911b) analyzed several extreme cases in *Paramecium* in which a body contained as many as fourteen oral regions. Heteromorphosis has been described in *Bursaria* (Lund, 1917) and in the related *Condylostoma* (Tartar, 1938b). Careful study of nuclear activity is needed in all such instances as these.

Even conceding it an active rôle in morphogenesis, the nucleus might conceivably function merely as an orienting agent for formative substances elaborated in the cytoplasm. There is no evidence, however, that this is the case. On the other hand, it has been shown in various connections that the nucleus may secrete substances into the cytoplasm. A more probable mechanism, therefore, involves the active secretion of stuffs by the nuclear apparatus (macronucleus in ciliates) during periods of morphogenesis.

Difficulties of direct demonstration are intrinsic in the material itself, especially in relatively small, motile organisms like the ciliates. Some of the larger unicellular algae also have long been subjected to regeneration experiments. These provide more favorable material for various

reasons; they are large, can be dissected readily, and even enucleate, chlorophyll-bearing fragments are viable for long periods. Recent work on *Acetabularia*, a complex uninucleate form related to *Valonia*, has led Hämmerling (1934a and b) to some important discoveries of pertinence to the present discussion. This alga is highly polarized, consisting of a basal rhizoid with the single nucleus, an erect stalk, and a reproductive umbrella. By testing the regenerative potencies of fragments of individuals at different ages, Hämmerling discovered a remarkable nuclear control of morphogenesis. He was able to make quantitative biological assays of the formative influence, which seemed to be of a substantive nature. His conclusion was that formative substances originate in the nucleus and act along concentration-gradients which have their high points at sites of morphogenesis. If corroborated (and the data seem to be exceptionally clear-cut), this will prove to be the most direct evidence yet discovered of a causal mechanism in regeneration. A direct link can thereby be established between the production, distribution and action of morphogenetic substances, although they have not yet been identified chemically. It has been suggested that their migration in definite directions is probably due to the existence of physiological gradients similar to those identified in other plants and in animals.

The applicability of this mechanism to protozoan regeneration must be left to future investigations. It provides suggestive data which are in agreement with all of the known facts in Protozoa. It has been seen that Calkins' investigation of *Uronychia* (1911a) indicated that some kind of formative stimulus probably was transmitted from nucleus to cytoplasm (see *Ciliata*, above). His conclusion contained a supposition (adapted from speculations by deVries and R. Hertwig) that is especially interesting in the light of the recent work on *Acetabularia*. It may well serve as the working-hypothesis for investigating the next important phase of the problem of regeneration in Protozoa: ". . . substances are formed in the nucleus and transferred to the cytoplasm, where they or the products of their activity accumulate until a condition analogous to saturation is reached. Cutting the cell at this period results in the exhaustion, through regeneration, of these substances . . ." (p. 115).

V. SUMMARY

1. An attempt has been made to treat comprehensively some of the major problems associated with regeneration in Protozoa.

2. The capacity for regeneration has been demonstrated in all principal groups of free-living Protozoa. The data involving parasitic forms (Sporozoa, etc.) are still too incomplete to permit of any definite conclusions.

3. From the available facts, it seems clear that the course of regeneration in each group is restricted by the developmental possibilities common to that group. In other words, regeneration involves the experimental counterpart of the normal limits of reorganization that occur at various phases of the life-history. This becomes explicable when we consider that one basic mechanism probably acts both during normal and experimental reorganization.

4. Few experiments have been performed on flagellates (Mastigophora), and these have involved complex forms of the Dinoflagellida and Volvocidae.

5. The pseudopodia-bearing Sarcodina have yielded some valuable results. In all instances the restoration of extirpated structures is dependent on the presence of

nuclear substance; even the more highly evolved groups have retained a high regenerative capacity.

6. The ciliates have yielded the most extensive data on regeneration. Their complex organization permits a great variety of experimental procedures.

(*a*) Of the dual nuclear apparatus, only the macronucleus can be shown to function in the actual regenerative process. The rôle of the micronucleus in this connection is as yet unclear; apparently it is more important in the viability of some forms than in others.

(*b*) The series of advancing structural complexity in the ciliates involves primarily a specialization of the oral region and of locomotor organelles. Correlated with this, the regenerative response tends to become restricted to the activity of *anlagen* of the organelles involved. This has been illustrated in the review by the comparative responses of the holotrichous *Paramecium*, the heterotrichous *Stentor* and the hypotrichous *Stylonychia*. In the Hypotrichina the regenerative response has become so highly integrated that removal of one motile organelle causes the complete reorganization of all locomotor and oral structures. These invariably develop in the same manner: primary differentiation within a reorganization field, and subsequent migration to their definitive positions. Evidence is given of physiological differences in the cytoplasm of young and adult individuals (Bauer and Granowskaja), which may throw some light on the data of Calkins (1911a), etc.

(*c*) Ciliates retain a marked regenerative capacity during the processes of fission, encystation and conjugation. Cutting experiments during fission often produce truncate offspring, attesting the presence of an irreversible division zone. The regenerative capacity during conjugation apparently is dependent on development of the new macronuclear anlage following meiosis.

7. Physiological regeneration has been reported in many Protozoa, and involves spontaneous replacement of structures. Evidence is available that at least some of these reports probably have mistaken restorative regeneration (induced by environmental stimuli) for a "normal growth process." Further investigations are highly desirable.

8. The nature of the mechanism underlying regeneration is still unsolved. There are many data, indirect and direct alike, which suggest an active, guiding rôle by the nuclear apparatus (macronucleus in ciliates). The nucleo-plasmic ratio may play an important part, but probably it comprises at best only one of a complex set of factors.

9. Recent work on *Acetabularia* may offer a promising working-hypothesis of a regenerative mechanism in Protozoa. In this unicellular alga formative stuffs are produced by the nucleus and are distributed along concentration-gradients to sites of morphogenesis. The activity of physiological gradients, such as have been demonstrated for Protozoa and other organisms, might explain the directional movements involved.

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Note: Several previous investigations of the author, some in Russian, are summarized adequately in his review. See that bibliography for further details.

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ACQUIRED IMMUNITY FROM PLANT VIRUS DISEASES

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ACQUIRED immunity from virus diseases has been studied by a number of phytopathologists in the decade since 1928. Much of the literature on the subject has not, however, come to the attention of biologists in general. Moreover, plant virus workers in many instances have apparently failed to recognize the significance and usefulness of the immune reaction for determining natural relationships of plant viruses. For these reasons, a general review paper may be of value to those who wish to acquaint themselves with progress in the field. In order to avoid lengthening the paper unnecessarily, discussion will be restricted entirely to virus diseases. The literature on the highly controversial subject of acquired immunity from bacterial and fungous diseases of plants was reviewed by Chester (19) in 1933.

THE MEANING OF ACQUIRED IMMUNITY

A clear understanding of what is meant by acquired immunity is necessary for proper evaluation of the data and conclusions which follow. While not all pathologists agree as to what constitutes acquired immunity, there seems to be general agreement in medicine that it is relative rather than absolute (55, 15, 25, 101, 106, 118). From this viewpoint, it may be defined as the resistance an individual organism acquires to a disease. It is necessary to add further that this resistance is specific in order to exclude changes in susceptibility induced by nutrition or aging of the host and by such environmental factors as would be apt to alter resistance not only to the disease in question but also to various other unrelated diseases.

Acquired immunity may be either active or passive. It is active if induced by infection with a parasitic agent, passive if induced by injection with immune serum or antibodies obtained from other individuals. Active immunity is well known in virus diseases of both animals and plants. On the other hand, passive immunity, well known in virus diseases of animals, has not been demonstrated in plants and need not be further considered here. (Since this paper was prepared for publication certain experiments reported by Wallace (Phytopathology *30:* 673-679, 1940) were interpreted as giving evidence of the presence of antibody-like substances in tobacco plants recovered from the curly top disease.)

Active immunity may be classified into three types, the chronic-disease type, the carrier type, and the sterile type. The chronic-disease type involves neither disappearance of the immunizing disease nor disappearance of the causal agent. The individual becomes solidly immune from a severe type of disease but suffers from a chronic mild disease. The carrier type

of acquired immunity involves persistence of the disease agent but disappearance of obvious manifestations of disease. In some diseases inducing this type of immunity, the individual is permanently protected from a second attack even when subjected to massive reinoculations with the infective agent. The sterile type of acquired immunity has not yet been demonstrated for plant virus diseases. In this type, not only do obvious signs of disease disappear, but the inciting agent disappears also, or at least cannot be detected by ordinary methods. The sterile type may be transitory or permanent and readily or with difficulty broken down by massive inoculation. Finally, it must be recognized that there is no sharp line of division between the three types of acquired immunity. The extent to which the concentration of the pathogenic agent is reduced determines whether the immunity is of the sterile or carrier type. The extent to which signs of disease disappear determines whether it is of the carrier or chronic-disease type.

In the discussion which follows, acquired immunity from plant virus diseases will be considered under two main headings, immunity following recovery from disease and, second, cross immunity in which infection with one strain of a virus protects from infection by closely related strains of the same virus. The immunity following recovery from disease is of the carrier type. Cross immunity may be either of the carrier or of the chronic-disease type.

IMMUNITY FOLLOWING RECOVERY FROM DISEASE

Tobacco ring spot. Tobacco ring spot was the first virus disease of higher plants in which acquired immunity was demonstrated. The disease was first described by Fromme and Wingard (34) in 1922 but is known to have existed as early as 1917 in tobacco fields of Virginia. Its infectious nature was determined by Fromme, Wingard, and Priode (35). The causal virus is readily transmitted to susceptible plants by rubbing their leaves with a gauze pad saturated with juice from infected plants. Tobacco (*Nicotiana tabacum* L.) plants inoculated in this manner develop a characteristic type of lesion on inoculated leaves in about 3 days. The primary lesion consists of concentric necrotic rings alternating with normal green tissue, hence the name, ring spot. In 3 or 4 more days, the virus spreads systemically and produces secondary lesions similar to the primary ones but generally larger and more irregular. In from 12 to 35 days after inoculation, depending on the growth rates of infected plants and their age when inoculated, diseased tobacco plants begin to recover. Recovery is initiated by the development of leaves in which lesions are confined to apical portions, leaving the basal portions healthy in appearance. The healthy-appearing basal portion and the diseased apical portion are usually demarcated by irregular necrotic lines which tend to follow along veins and form an outline similar to that of an oak leaf. In subsequently produced leaves, the lesions and oak-leaf patterns are restricted to progressively smaller areas at the leaf tips until, finally, such symptoms completely fail to appear (Fig. 1). Leaves produced after this stage has been reached closely resemble those of healthy plants but are slightly darker in color, somewhat thicker, and of a more leathery texture. Recovered plants appear to grow somewhat less rapidly than healthy plants.

Wingard (115) was the first to report recovery from tobacco ring spot and to suggest that certain plants might acquire immunity from this disease. He failed

to produce ring-spot symptoms on recovered leaves by inoculating them heavily with ring-spot virus. The recovered plants were not, however, free of virus, and juice from recovered portions readily produced typical ring-spot symptoms when used to inoculate healthy plants. Wingard transmitted the disease to plants of 38 genera in 17 different families and reported that "this masking of symptoms, or development of immunity, or whatever it is, seems to hold under greenhouse conditions for practically all the plants tested." Henderson and Wingard (38) confirmed Wingard's original observation and reported further that the symptoms remained "masked" for a period of a year in tobacco plants grown through several generations by cuttings from recovered plants.

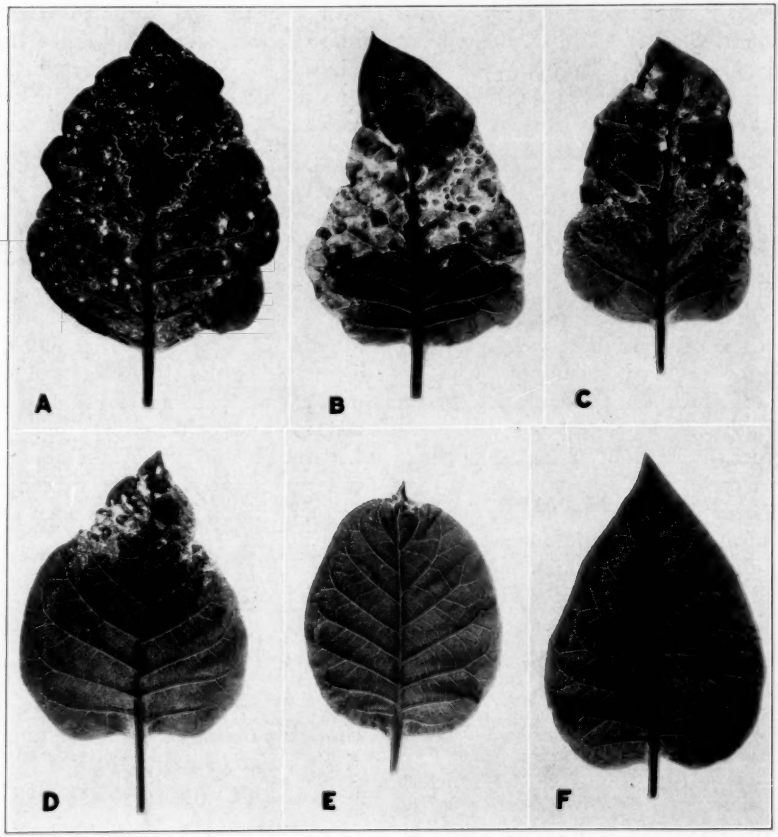

FIG. 1. LEAVES OF TURKISH TOBACCO ILLUSTRATING SUCCESSIVE STAGES IN RECOVERY FROM RING SPOT

A, leaf produced early in the course of the disease, showing acute symptoms; B, to E, leaves produced later, showing progressively fewer symptoms; F, healthy-appearing leaf produced still later after the plant had recovered. (After Price, 76.) (Photograph by L. P. Flory.)

The observation of Wingard was of considerable importance to plant pathology since here, for the first time, was definite evidence that plants might acquire immunity from disease—something hitherto regarded as unlikely by most plant pathologists. On the other hand, it was possible to explain his observation on the basis of masking of symptoms. Masking occurs when plants are grown under conditions unfavorable for symptom expression, the symptoms reappearing when the conditions become favorable. It had previously been observed for other virus diseases (36, 50, 10).

Price (76) therefore made a special study of tobacco ring spot in order to determine whether the condition reported by Wingard really was acquired immunity or whether it was merely masking of symptoms. He was able to confirm the observations previously reported that tobacco and certain other species of plants invariably recover from tobacco ring spot, that the healthy-appearing leaves of recovered plants carry the virus, and that they cannot be induced to produce symptoms by reinoculation. He showed further that this recovery and immunity to reinfection takes place under a wide range of environmental conditions and that it is entirely distinct from the masking of symptoms that occurs in the case of a few other virus diseases under certain environmental conditions. Plants grown under favorable environmental conditions from cuttings of recovered plants were repeatedly inoculated with ring-spot virus, but in no case did symptoms develop, whereas plants grown from cuttings of healthy plants and treated in exactly the same manner invariably came down with the disease (Fig. 2). Acquired immunity was thus demonstrated for 4 species of *Nicotiana* and for 10 varieties of *N. tabacum*. It was concluded that the phenomenon observed constituted an acquired immunity similar to that which obtains in the case of many virus diseases of animals.

Valleau (110, 111) concluded that tobacco plants do not recover and do not acquire immunity from tobacco ring-spot disease. He maintained that symptoms are produced only when the growing point of the plant has not been completely invaded by virus, that leaves developed subsequent to invasion are parasitized although patternless, and that inoculation of patternless leaves is without effect since the cells are already parasitized to the limit (presumably the same limit as the cells of diseased plants).

Studies by Price (80) on virus concentration in recovered plants led to the conclusion that cells of recovered plants are not parasitized to the limit, as Valleau had suggested. It was demonstrated that virus multiplies in the cells of recovered plants but not to the same extent as in recently infected plants grown under the same conditions. The recovered portions of affected plants were found to contain, on the average, only from 10 to 20 per cent as much virus as the diseased portions of the same plants. It should be mentioned in this connection that Stanley (98) isolated a virus protein from recovered plants apparently identical with that obtained from diseased plants, but it was present in only $\frac{1}{6}$ the amount. The line of demarcation between areas of high and low virus titer is very sharp. The healthy-appearing basal portions of partly recovered leaves contain significantly less virus than the diseased apical portions of the same leaves (80). No differences were found between apical and basal portions of either fully recovered or fully diseased leaves. The virus concentration of re-

covered leaves was not apparently increased by inoculating them heavily with ring-spot virus. The observations reported suggest that there is a mechanism by means of which recovered plants restrict the multiplication of ring-spot virus, a mechanism not possessed by healthy or recently infected plants.

In discussing the meaning of acquired immunity, it was stated that the resistance acquired must be specific. Acquired immunity from tobacco ring spot meets this criterion, since tobacco plants that have recovered from ring spot are susceptible to infection by tobacco-mosaic, cucumber-mosaic, potato vein-banding, potato ring-spot, tomato spotted-wilt, etch, and severe-etch viruses and, no doubt, to all other tobacco viruses that are not closely related to ring-spot virus (81). They are immune from or highly resistant to infection by closely related viruses such as those causing Valleau's (109) green and yellow ring-spot diseases.

Tobacco ring spot No. 2. A second virus disease from which plants recover and acquire immunity is tobacco ring spot No. 2, first described by Price (81). The virus concerned is readily transmitted by mechanical inoculation and induces, in Turkish tobacco, primary and secondary zonate necrotic lesions similar to those of ordinary tobacco ring spot. Systemically infected tobacco plants show recovery characterized by the development of zonate oak-leaf patterns, and by the eventual production of leaves that are entirely symptomless. Leaves of recovered plants harbor the virus of the disease in considerable quantity and they do not develop necrotic-ring symptoms upon reinoculation even when borne on rapidly growing plants propagated by means of cuttings from recovered plants.

FIG. 2. NICOTIANA TABACUM VAR. PURPUREA 16 DAYS AFTER INOCULATION WITH RING-SPOT VIRUS
The plant on the left, which shows no symptoms other than the injury produced by rubbing, was grown from a cutting of a plant that had recovered from ring spot. The plant on the right, which shows typical symptoms, was grown from a cutting of a healthy plant. (After Price, 76.) (Photograph by L. P. Flory.)

Plants that have recovered from tobacco ring spot No. 2 are solidly immune from this disease but are susceptible to infection by viruses of ordinary tobacco ring spot, including the green and yellow strains, and by the viruses of tobacco mosaic, cucumber mosaic, potato vein banding, potato ring spot, tomato spotted wilt, etch, and severe etch. Conversely, plants that have recovered and are immune from ordinary tobacco ring spot, or the green or yellow form of the disease, are readily susceptible to tobacco ring spot No. 2. This observation affords an excellent example of the specificity of acquired immunity from these plant virus diseases.

Tobacco streak. Tobacco-streak disease, first described by Johnson (53), has been known for at least 18 years. It is transmitted readily by mechanical inoculation. The symptoms of tobacco streak consist of necrotic lesions confined entirely to the leaves. The lesions may be either solid necrotic spots, necrotic rings, or necrotic etch-like patterns following along the veins. After systemic invasion, tobacco plants infected with the disease invariably recover by the production of new leaves that do not show necrotic symptoms. Recovered plants carry the virus of tobacco streak and occasionally show clearing-of-veins and mild mottling. The recovery apparently bears no relation to the external environmental conditions. Reinoculation of recovered plants, in contrast to inoculation of healthy controls, fails to produce an attack of the necrosis. Plants that have recovered from tobacco streak are susceptible to infection with tobacco-mosaic, cucumber-mosaic, tobacco ring-spot, potato ring-spot, potato-mottle, and potato vein-banding viruses. Conversely, plants infected with these viruses are still susceptible to infection with tobacco-streak virus (54).

In his first report on tobacco streak, Johnson (53) suggested that the recovery and subsequent immunity to the typical disease constituted acquired resistance. After making a thorough study of recovery from tobacco streak, he (54) came to the conclusion that the phenomenon was a good example of acquired immunity from a plant virus disease, and suggested that artificial immunization might be used as a practical control measure for virus diseases of vegetatively propagated plants.

Bergerac ring spot of tobacco. A fourth virus disease from which plants recover and probably acquire immunity is Bergerac ring spot of tobacco. The causative virus was isolated at Bergerac in southwestern France by Smith (96, pp. 285–289). Tobacco plants affected by the disease show typical ring-spot symptoms from which they eventually recover, although they still carry virus. Thus, the recovery is similar to that which occurs in the other ring-spot diseases and in tobacco streak. Smith states that no cross immunity exists between Bergerac ring spot, tobacco ring spot, and tobacco ring spot No. 2. He thus implies that plants recovered from Bergerac ring spot are immune from a second attack of this disease, although he does not specifically state this to be the case.

Sugar-beet curly top. The four virus diseases so far considered are similar in producing necrotic ring-spot symptoms. Sugar-beet curly top, on the other hand, is a yellows-type disease characterized by yellowing without the production of discrete lesions. The report by Lesley and Wallace (66) that certain races of tomato (*Lycopersicon esculentum* Mill. and *L. pimpinellifolium* Mill.) recover and acquire immunity from curly top is therefore of considerable interest. This immunity is not of so high an order as in the ring-spot and streak diseases. In-

fected plants do not always recover; those that recover occasionally show a relapse, and they may, in a few instances, develop severe symptoms when reinoculated.

Young tomato plants infected with curly top late in spring develop the disease in about 12 days. The leaves become rolled, growth is stunted, flowers and buds drop, the fruit colors prematurely, and the plant as a whole assumes a sulphur-yellow color. As a rule the infected plant dies. However, in certain races of tomato, from 10 to 100 per cent of infected plants recover from the disease by production of healthy-appearing shoots from axillary buds. When propagated vetetatively by cuttings, recovered plants are relatively slow-growing and have other mild symptoms of disease. Reinoculation of such plants fails as a rule to produce any further symptoms in them in contrast to the severe symptoms produced in healthy plants propagated from cuttings. No attempts have as yet been made to determine whether the immunity is specific for the curly-top disease. It perhaps should be stated that Lesley and Wallace referred to recovery from curly top in tomato as acquired tolerance, not as acquired immunity. (See the section on "The meaning of acquired immunity.")

Potato yellow dwarf. Another virus disease from which certain species of plants recover and acquire immunity is yellow dwarf of potato. Black (12) has emphasized that there are two distinct phases of the disease in potato (*Solanum tuberosum* L.), an acute stage and a chronic stage. Symptoms of the acute stage have been described in detail by Barrus and Chupp (4). The dwarfed condition of affected plants and their yellow color give the disease its name. Infected stalks are short, become yellowish green in color throughout, and develop internal and and external necrosis. The growing tip becomes yellowed and necrotic and dies; axillary buds also die, but somewhat later. Tubers produced by diseased plants show various degrees of internal necrosis and are knobby and cracked. The few plants grown by Barrus and Chupp from diseased tubers showed symptoms similar to those which Black (12) attributes to the chronic stage of yellow dwarf. The chronic stage is found in plants that have recovered by production of new growth from axillary buds (Fig. 3). Such new growth, besides being somewhat dwarfed and spindling, also shows clearing-of-veins and a mild mottling. However, the uppermost leaves do not yellow and die as in the acute stage. Recovered plants, furthermore, do not develop the severe internal apical necrosis characteristic of the onset of the disease. Recovered plants have been grown through five vegetative generations without again developing acute symptoms of yellow dwarf. Recovery from yellow dwarf occurs regularly and is not due to special environmental conditions or to attenuation of virus. Although Black did not specifically refer to this recovery as acquired immunity, he pointed out that the pathogenic activity of the virus was checked by a change within the plant. It is clear that he believed an increased degree of resistance was elicited. A similar type of recovery was observed in medium red clover (*Trifolium pratense* L.) and crimson clover (*T. incarnatum* L.) plants infected with potato yellow dwarf (12, 13).

Other diseases. There may be many other diseases, besides those already mentioned, in which plants normally recover and become immune from a further attack. Johnson (54) has, in fact, suggested that the presence of potato ring-spot and potato-mottle viruses in all

standard varieties of American potatoes without the production of symptoms may be due to an acquired immunity on the part of the potato. Before this conclusion can be accepted, it will be necessary to determine whether potatoes infected with the virus for the first time develop a disease from which they later recover. For it is possible that infection of the original potato stock resulted in no symptoms whatever. There are numerous instances of plants being infected by viruses without the production of symptoms. Such plants are usually referred to as "masked" or "symptomless" carriers. They may not remain symptomless under all environmental conditions. For instance, Nishimura (73) reported *Physalis alkekengi* L. to be a masked carrier of tobacco-mosaic virus. However, as pointed out by Holmes (42), *P. alkekengi* occasionally shows mottling symptoms. In the tip leaves of symptomless plants, virus, if not completely absent, is present only in low concentration, but in mottled leaves is present in high concentration. This implies that failure to produce symptoms results from a failure of virus to multiply extensively in very young growing tissues.

FIG. 3. A GREEN MOUNTAIN POTATO PLANT INFECTED WITH YELLOW DWARF
The main axis shows severe symptoms of the acute stage. The axillary shoot shows progressive recovery to the chronic stage. (After Black, 12.) (Photograph by W. R. Fisher.)

Tomato plants inoculated with the Y virus develop clearing-of-veins and other mild symptoms of disease. The mild symptoms rapidly disappear and the plant

then carries the virus without showing further symptoms (90). Smith (92) compared the recovery from the disease produced by potato-Y virus with that which occurs in tobacco plants infected with ring-spot virus and suggested that it constituted acquired immunity though not in the usual conception of the term. There are a number of other virus diseases from which certain species of plants show a similar type of recovery. Köhler (57) described such recovery in tobacco plants infected with a mixture of potato X and Y viruses. Whether such cases as the two here mentioned can properly be regarded as acquired immunity is open to question and must await further study. At the present time it is not known whether the recovery is more than a masking of symptoms brought about by aging of the host plant.

Symptoms of certain virus diseases, such as tobacco mosaic and cucumber mosaic in tobacco, are at first severe, but the onset stage of the disease is followed by the production of a whorl of leaves that are either healthy in appearance or show only mild symptoms. The escape of these leaves may be due either to slow spread of virus or to a change in susceptibility of the host tissue. If it is an immune reaction, it is of a relatively low order, since subsequently produced leaves show mottling symptoms and the recovery is thus only a temporary one. Comparison of virus concentration in the leaves produced before and after the recovery might reveal whether or not the virus activity is checked and might thus be of value in arriving at an understanding of this phenomenon.

CROSS IMMUNITY

Virus strains. Before taking up in detail the second type of acquired immunity from plant virus diseases, it might be well to digress for a moment to examine what is meant by virus strains and how they arise. In the early days of plant virus research, it was a common belief that one virus was the cause of many, if not all, virus diseases of plants—that there was one mosaic disease that attacked a great variety of plants. Thus, as late as 1925, Elmer (32) spoke of transmissibility and pathological effects of the mosaic disease as though there were only one such disease. As new experimental evidence became available, however, it came to be recognized that more than one virus was involved in the many mosaic diseases of plants; that, for example, tobacco mosaic would attack certain plants but not others; and that these others were often affected by mosaic diseases that differed from tobacco mosaic. This recognition led to a search for new viruses and to a propensity among phytopathologists to ascribe a new virus to each new virus disease discovered. Thus there developed a tendency for differentiating between viruses on minor symptom or host range differences—and this tendency persists to a limited extent even to the present day. Gradually, however, it was realized that there are groups of viruses, each markedly different from other groups but made up of strains very much alike in some respects and differing slightly in others. At first, viruses were grouped on the basis of their physical properties, such as resistance to heat, aging, and various chemicals, their host range, and their transmission by insect vectors. Although it is still necessary to use such criteria for differentiating and classifying many plant viruses, more exact methods are available for others. Two of the most important methods in use today are the serological method developed by Dvorak (29), Beale (7), Matsumoto (68), Silberschmidt (89), Birkeland (11), Chester

(20), and others, and the plant cross immunity tests which will be dealt with below in considerable detail.

Virus strains belonging to various groups have been recognized in nature and have also been obtained under experimentally controlled conditions. For instance, attenuated strains of sugar-beet curly-top virus have been secured by passage of the virus through resistant varieties of sugar beets or through resistant weed hosts (17, 18, 64, 65) and attentuated strains of tobacco-mosaic virus by incubation in host tissues at relatively high temperatures (51, 43, 58). Mild strains of aster-yellows virus were isolated from the insect vector when colonies of the vector were maintained at high temperatures (61, 62). Various strains of tobacco-mosaic virus have been isolated from bright yellow spots that appear in tomato plants infected with ordinary tobacco mosaic. McKinney (69) was the first to show that yellow-mosaic viruses may be isolated by subinoculation from yellow spots, and he (70) suggested the possibility that these viruses arise by mutation from the ordinary strain. He (71) also found that a yellow-mosaic virus may be obtained in a similar manner from wheat (*Triticum aestivum* L.) plants infected with ordinary wheat mosaic. Jensen (46, 47) found that variant strains arise during multiplication of ordinary tobacco-mosaic virus in infected plants, apparently by a process similar to mutation. Virus of tobacco mosaic freed from all other viruses by serial passage through the necrotic primary lesions it produces in *Nicotiana glutinosa* L. subsequently gave rise to variant strains when transmitted to plants in which it became systemic. Virus purified by several other methods was likewise found eventually to produce mutant strains. A total of 51 such strains were isolated and studied by Jensen (46, 47, 48). The number has been considerably augmented by later studies (44, 74).

It is probable that mutations occur not only in tobacco-mosaic virus but also in most if not all, plant viruses. They have been shown to occur, for instance, in cucumber-mosaic virus (77, 39). It thus seems likely that many of the virus strains existing in nature have arisen, at some time in the past, by mutation from some other virus and that these virus strains may be classified into groups the members of each of which are genetically related (59).

Demonstration of cross immunity. The first indication that one strain of a virus might protect plants from infection with another strain was an observation by McKinney (70) in 1929. He found that when tobacco plants infected with a light-green-mosaic virus were inoculated with a yellow-mosaic virus, no change in symptoms occurred. However, plants infected with a mild-dark-green-mosaic virus developed yellow-mosaic symptoms when inoculated with the same yellow-mosaic virus. It appears unlikely that McKinney regarded the protection by the light-green-mosaic virus as acquired immunity, for he merely mentioned the experiment casually and did not report any further study of the matter. Later writers were apparently unaware of McKinney's observation, as no further reference to it has been found in the literature.

From ordinary tobacco-mosaic virus, Thung (104) isolated a yellow-mosaic virus similar to McKinney's (70) yellow-mosaic virus and Johnson's (52) tobacco virus 6. Plants infected with ordinary mosaic developed no change in symptoms when inoculated with the yellow-mosaic virus. Similarly, plants infected with yellow mosaic developed no change in symptoms when inoculated with the

ordinary mosaic virus. Moreover, only one virus could be isolated from the doubly inoculated plants, the one first introduced. These results led Thung to conclude that only one of the two virus strains could multiply extensively in any given cell.

Following Thung's original studies, Salaman (85) made similar experiments with strains of the potato-X virus. By subinoculating from green and yellow areas, respectively, of a tobacco leaf affected by the X virus, he obtained two strains—an exceedingly mild type (G) and a severe yellow type (L). Plants infected with the mild G type, whether showing definite symptoms or not, were protected from subsequent infection with the severe L-type virus. Salaman concluded that plants with the L strain had acquired immunity from the G strain. The immunity developed on the 5th day after inoculation and about 4 or 5 days before systemic symptoms of the G strain appeared. It seemed to be specific, since it was effective against other strains of the X virus but not against the potato-Y virus or the common tobacco-mosaic virus.

Oortwijn Botjes (75) showed that plants of certain potato varieties infected with either secondary top necrosis or attenuated top necrosis are, as a rule, protected against primary top necrosis, a more virulent disease. The viruses concerned in this work are probably identical with, or closely related to, those used by Salaman (85), since it is stated by Oortwijn Botjes that the virus of top necrosis is known in America as the healthy-potato virus which in turn is known to be the same as, or a strain of, the X virus of English workers. The results of Oortwijn Botjes and Salaman were confirmed by Köhler (57) who reported that both tobacco and potato infected with one strain of potato-X virus were protected from infection with another strain of potato-X but not from infection with potato-Y virus.

Kunkel (58) made a thorough study of acquired immunity with tobacco- and aucuba-mosaic viruses in *Nicotiana sylvestris* Spegaz. and Comes. In many tests, mature mottled leaves of plants systemically infected with ordinary tobacco-mosaic virus or with either of two attenuated strains of aucuba-mosaic virus were immune from a necrotic-type aucuba-mosaic virus. The protection afforded was very striking, since control plants inoculated with aucuba-mosaic virus came down with numerous necrotic lesions, whereas no such lesions developed in mottled leaves. Subinoculations from mottled leaves that were rubbed with aucuba-mosaic virus failed to demonstrate the presence of the necrotic-type virus. Mature leaves became immune from aucuba-mosaic virus within 2 days after they had been rubbed with attenuated virus (Fig. 4). In order to protect completely against aucuba-mosaic virus, it was necessary to inoculate heavily with attenuated virus so that all parts of the leaves became infected. No evidence was obtained that tissues free of virus, whether or not adjacent to virus-infected tissues, became immune. However, local protection was not confined to cells actually inoculated; inoculation of the lower surface of a leaf was capable of protecting the leaf from infection by a subsequent inoculation of the upper surface, although 5 cell layers intervene between the upper and lower epidermal cells. Acquired immunity from aucuba mosaic is specific. Protection was afforded by previous infection with all strains of tobacco- and aucuba-mosaic viruses tested, but not by previous infection with cucumber-mosaic or tobacco ring-spot viruses.

Interesting examples of acquired immunity from strains of tobacco-mosaic virus have recently been reported by Kunkel (63). A mild strain of tobacco-mosaic virus, designated as V-9, was used to immunize *Nicotiana sylvestris* plants completely from a lethal strain, J-111, which invariably causes the death of unprotected *N. sylvestris* plants. Strain V-9 was also used to immunize tomato plants from infection with strain J-14D, a virus which quickly kills normal tomato plants to which it is transmitted. Interestingly enough, tomato plants were saved from death or serious injury when they were inoculated with the protecting virus, V-9, within 3 days after they had become infected by J14D. They could not be saved in this manner if they had been infected with the lethal virus for longer than 3 days.

Acquired immunity of *Zinnia elegans* Jacq. from cucumber mosaic has been studied by Price (78). It was found that mottled leaves of plants infected with any one of 4 different strains of cucumber-mosaic virus became immune from infection with a necrotic-type strain. They were, however, susceptible to a necrotic-type tobacco-mosaic virus. Furthermore, zinnia plants infected with tobacco mosaic, aucuba-mosaic, tobacco ring-spot, yellow-ring-spot, or severe-etch virus did not acquire immunity from the necrotic-type cucumber-mosaic virus. The immunity induced in zinnia by cucumber-mosaic virus was thus shown to be highly specific.

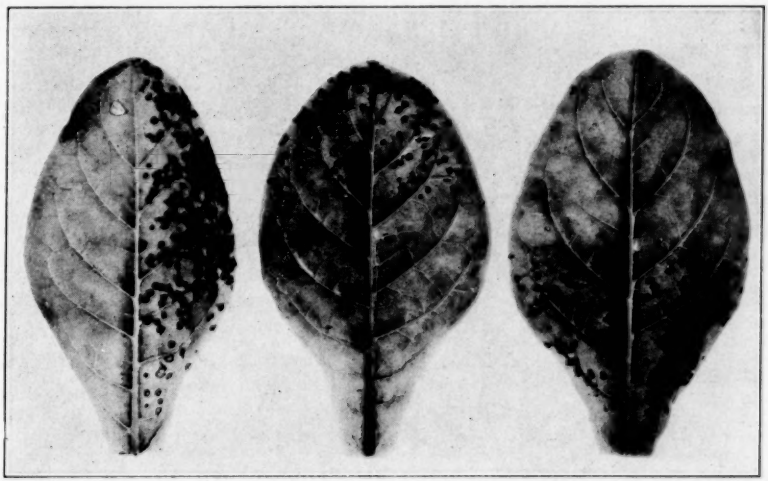

FIG. 4. LEAVES OF NICOTIANA SYLVESTRIS SHOWING NECROTIC LESIONS PRODUCED BY AUCUBA-MOSAIC VIRUS
The lesion-free areas were immunized by inoculating them heavily with tobacco-mosaic virus 5 days before the entire leaf surfaces were rubbed with aucuba-mosaic virus. (After Kunkel, 58.) (Photograph by J. A. Carlile.)

The cross immunity reactions discussed so far have been concerned with viruses readily transmitted by mechanical inoculation. The immunological studies by Kunkel (60) on the yellows, rosette, and little-peach diseases of peach (*Prunus persica* Sieb. and Zucc.) are of special interest because these diseases are transmitted only by insects or by grafting. All 3 diseases cause stunting, the abnormal

production of secondary shoots, and yellowing of mature leaves. Little peach is the least severe of the 3, rosette the most severe. Kunkel has shown that peach trees having the little-peach disease are solidly immune from yellows. Similarly, trees infected with yellows are immune from little peach. On the other hand, trees having either yellows or little peach are fully susceptible to rosette. All the immunity tests were made by insertion of one or more diseased buds into the stem of the tree to be tested. When a bud from a yellows tree was transplanted to a tree affected by little peach and allowed to grow, the bud not only failed to transmit the yellows disease but also produced shoots which invariably came down with little peach. Similarly, little-peach buds transplanted to yellows trees produced shoots which developed yellows. In other words, shoots from the transplanted bud developed the symptoms of the disease present in the stock, regardless of the virus carried in the bud (Fig. 5). Similar results were obtained even though the transplanted buds were removed from the diseased tree before they produced

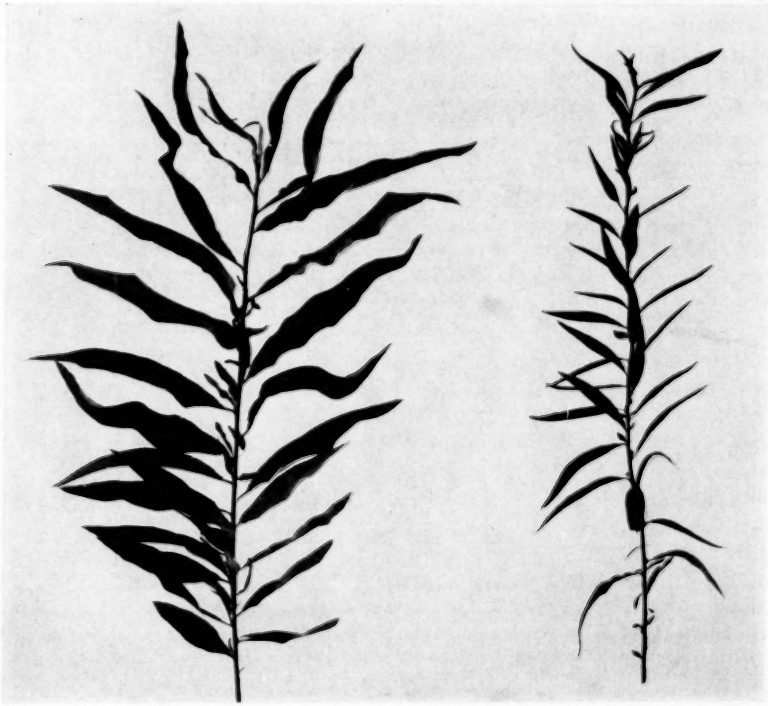

FIG. 5. PEACH TREE SHOOTS THAT GREW FROM TRANSPLANTED BUDS

The shoot on the left was from a yellows bud that grew in a little-peach tree; it shows the mild leaf distortion symptoms characteristic of little peach. The shoot on the right was from a little-peach bud that grew in a yellows tree; it shows characteristic yellows symptoms. Both shoots have developed symptoms of the disease present in the tree regardless of the virus carried in the bud. (After Kunkel, 60.) (Photograph by J. A. Carlile.)

shoots and were transferred to a healthy tree. When little-peach and yellows buds were inserted simultaneously at different levels into stems of healthy trees, the trees developed symptoms of the virus carried by the bud at the higher level. These results led Kunkel to suggest that under suitable conditions either the yellows or little-peach virus is capable of displacing the other in infected tissues. The means by which the displacement takes place is not known. Kunkel states that it apparently cannot be due to mass action, since approximately equal doses of the viruses are involved when two buds are transplanted to a tree on the same date.

Use of plant protection tests in differentiation and classification

The cross immunity reaction is extremely useful for differentiating and classifying plant viruses. It has been used for classifying viruses belonging in the potato-X virus group (85, 75, 1, 54), the tobacco-mosaic virus group (104, 105, 58, 93, 16), the cucumber-mosaic virus group (78), the tobacco ring-spot virus group (81), and the potato-Y virus group (87), among others. Price (81) used it to differentiate between tobacco ring spot No. 2 and other viruses. Immunity studies by Kunkel (60) showed that peach-yellows and little-peach viruses are related to each other but not to peach-rosette virus.

Bawden (5) found that potato-X virus and potato-D virus, which causes foliar necrosis in the potato, usually gave complete cross protection in tobacco, potato, and *Datura stramonium* L. He was thus led to suggest that potato-D virus might be classified in the potato-X virus group.

The mosaic disease of celery (*Apium graveolens* L.) first observed in Florida about 1924 (33) and later studied extensively (27, 28, 112, 113, 114) was thought to be distinct from, although similar to, ordinary cucumber-mosaic virus. Cross protection tests with southern-celery-mosaic virus in *Zinnia elegans* showed it to belong to the cucumber-mosaic virus group, a fact confirmed later by other lines of evidence (79).

The lily-mosaic disease has been known since the turn of the century (99) and was probably introduced into Bermuda about 1893 (116) where it caused a rapid decline in the lily (*Lilium* spp.) industry of the island. Cross protection tests have shown this disease to be induced by a virus belonging in the cucumber-mosaic virus group (82, 2). However, Brierley (14) has recently brought evidence that lily mosaic is caused by the interaction of two viruses, one of which is related to cucumber-mosaic virus and the other is similar to the color-removing virus of the tulip-mosaic virus complex (72).

Smith (94, 95) used plant protection tests as a means of differentiating between the virus of a new disease of tomato, now called bushy stunt, and the viruses of tobacco mosaic, tomato spotted wilt, tobacco ring spot, and Bergerac ring spot. He (96, pp. 285–289) also differentiated between the viruses of Bergerac ring spot, tobacco ring spot, and tobacco ring spot No. 2 by their failure to cross immunize.

Bald (3) used plant protection tests for differentiating between an F-type potato virus occurring in Australia and the Y, X, and a mixture of X and B viruses of potato. Bawden (6) found that potato plants infected with the X virus were not protected from infection when grafted with scions carrying both the X and B viruses. He was thus led to conclude that the B virus is probably distinct from the X virus. Dennis (26) recently separated the B virus from the mixture and

found that it gave no cross protection against potato-X virus in either *Datura stramonium*, potato, or toabcco. Since the X and B viruses have similar host ranges and almost identical properties so far as known, and since they can not be distinguished serologically, Dennis maintains that it is only because they do not show complete cross protection that they are believed to belong in different groups.

Storey (100) described a new virus of maize (*Zea mays* L.), which he calls the mottle virus. The results of immunity studies led him to conclude that the mottle virus is not related to the virus of maize-streak disease even though both viruses are transmitted by the same species of *Cicadulina*.

Price (83) made use of cross immunity tests to demonstrate that tobacco-necrosis virus, first described by Smith and Bald (97), is not related to tobacco ring-spot, tobacco ring-spot No. 2, tobacco-mosaic, cucumber-mosaic, or severe-etch viruses.

Dykstra (30, 31) used plant protection tests for differentiating between and classifying certain potato viruses. On the basis of these tests, he concluded that the European Y, the American vein-banding, and the potato stipple-streak viruses are interrelated, but not related to cucumber-mosaic virus, nor to the virus complex causing Di Vernon top necrosis, and that pseudo net-necrosis virus from Holland, tuber-blotch virus from Ireland, potato aucuba-mosaic virus, and Canada-streak virus are closely interrelated but not related to potato-calico virus.

Virus relationships as determined by plant protection tests are generally in accord with those determined by the serological method (8, 9, 20, 21, 23). In a few instances, however, some differences have been observed. For example, Chester (22) has shown that certain viruses, while having antigens in common and known to be closely related, nevertheless show minor serological differences. Furthermore, Chester (23) obtained cross-serological reactions between ordinary tobacco ring-spot and tobacco ring-spot No. 2 viruses, whereas no such cross reaction has been found by means of plant protection tests (81). The reason for these differences is not clear. In the first case mentioned, i.e., the serological differences between virus strains, it would appear that the serological method is more sensitive than the plant protection method, whereas in the second case the plant protection method would seem to be more sensitive. Virus relationships based on plant protection tests also agree reasonably well with those determined by symptomatology, host range, physical properties, and insect vectors.

Reliability of plant protection tests for determining virus relationships

It may be asked at this point: how reliable are plant protection tests for determining virus relationships? The evidence we have already considered favors the view that a plant cell infected with one strain of a virus cannot subsequently become infected with another strain of the same virus. It also supports the conclusion that a cell already infected will allow infection with, and multiplication of, unrelated viruses. From this it follows that, if one virus protects a plant from infection with another, the two viruses are doubtlessly related, and, conversely, if a virus does not protect cells from infection with a second virus, the two are probably unrelated. What, then, are the possible sources of error in practical application of cross protection tests? The reliability of the method would seem to depend, for the most part, upon the accuracy with which it can be determined

whether or not one of the two viruses, whose relationship is under question, is able to multiply in cells already occupied by the other virus. The accuracy with which such a determination can be made may become clear by consideration of two different types of protection tests.

The two types referred to are fundamentally alike—they differ only in that one depends upon evidence of systemic, the other upon evidence of local infection. Let us suppose that the two viruses under consideration are of the mosaic type, and both capable of producing systemic symptoms in a susceptible host. Let us assume further that one of the viruses is of the green-mosaic and the other is of the yellow-mosaic type. Plants are infected with the green-mosaic virus and allowed to become thoroughly mottled. They are then inoculated with the yellow-mosaic virus. If, after a suitable interval, yellow-mosaic symptoms have not developed in the infected plants but have developed in suitable controls inoculated with the same yellow-mosaic virus at the same time, it is reasonably safe to conclude that the green mosaic has protected the plant from infection with the yellow mosaic and that the two viruses are therefore closely related. If, on the other hand, the plant develops yellow-mosaic symptoms in addition to those of green mosaic, it is not so safe to conclude that the two viruses are unrelated. It is possible that the yellow-mosaic virus may have infected the plant through cells not actually invaded by the green-mosaic virus. A number of cells of a mottled leaf may be virus-free, although the majority of cells are infected. For example, it has been shown (40, 37) that in a leaf mottled by tobacco-mosaic virus, the yellow areas have a high concentration of virus whereas the green areas contain relatively little virus, and it is presumed that some of the cells of such areas are entirely free of virus. Such cells are probably susceptible to infection with another strain of tobacco-mosaic virus, for it has been shown by Kunkel (58) that only those areas actually invaded by a mottling strain of tobacco-mosaic virus are immune from infection with a necrotic-type strain—uninvaded areas are susceptible even though adjacent to infected tissue. Johnson and Valleau (49) have presented evidence to show that, if plant tissue is incompletely invaded by a mild strain of tobacco-mosaic virus, another strain of the virus can enter, multiply, move to the incompletely invaded tissue of the growing point, and eventually produce symptoms in the tip of the plant. Similarly, Holmes (43) has shown that a masked strain of tobacco-mosaic virus does not protect tobacco plants from systemic infection with a distorting strain, although it delays movement of the distorting strain and, hence, appearance of systemic symptoms. Further evidence bearing on this point is contained in the report by Bawden (5) that tobacco plants systemically infected with potato-D virus occasionally developed a few necrotic rings when subsequently inoculated with potato-X virus. By subinoculation from such rings, the X virus was obtained free from the D virus. This led Bawden to conclude that the areas in which the X virus had produced symptoms contained none of the D virus. In the case under discussion, infection of virus-free areas with yellow mosaic could conceivably be followed by systemic invasion. The actual number of infections would not have to be large—two or three primary infections will give rise to systemic symptoms almost, but not quite, as rapidly as several hundred primary infections (41). In plant protection tests based on appearance of conspicuous systemic symptoms, it may be concluded

that a positive protection is indicative of virus relationship but that negative results are not entirely satisfactory for differentiating between two viruses.

Protection tests based on evidence of local infection are considerably more satisfactory. Multiplication at the site of inoculation may be detected by the production of yellow or necrotic primary lesions or by subinoculations to a host plant that will allow the two viruses under test to be distinguished. Both methods may be illustrated with tobacco- and aucuba-mosaic viruses in *Nicotiana sylvestris* (58). When a leaf thoroughly mottled by tobacco mosaic is inoculated with aucuba-mosaic virus, no lesions develop, but if a leaf mottled by an unrelated virus, such as cucumber-mosaic virus, is likewise inoculated with aucuba-mosaic virus, a large number of lesions develop. The production of lesions is evidence that multiplication has occurred. Additional evidence that virus multiplication has or has not occurred can be obtained by subinoculation to healthy *N. sylvestris* plants. Since tobacco-mosaic virus does not produce necrotic lesions in this plant, the development of such lesions indicates presence of aucuba-mosaic virus and the failure to develop lesions, absence of the virus. It is thus seen that plant protection tests based on evidence of virus multiplication at the site of inoculation may furnish conclusive evidence not only that two viruses are related but also that other viruses are unrelated. Such tests are therefore much superior to those involving only systemic symptoms. Since viruses that produce distinctive primary lesions are required for use in the former type of test, it would seem desirable to search for representative virus strains that possess this characteristic. Examples of virus groups comprising both mottling-type and necrotic-type viruses are the tobacco-mosaic, cucumber-mosaic, and potato-X virus groups. Undoubtedly, other such groups will be found when sufficiently exhaustive studies have been made.

What has been said here need not discourage plant protection tests in virus groups which, so far as known, do not contain strains that produce readily detected primary lesions. Such tests may be quite useful; indeed, they have already proved useful in certain cases (60). It should be borne in mind, however, that failure to obtain cross protection between mottling-type viruses may indicate failure of the viruses to become completely systemic rather than a lack of relationship between them.

THE MECHANISM INVOLVED IN ACQUIRED IMMUNITY FROM PLANT VIRUS DISEASES

Practically nothing is known regarding the mechanism responsible for acquired immunity from plant virus diseases. Any theory that is suggested to explain the condition is, therefore, highly speculative. Certain hypotheses have been formulated, however, and it seems worthwhile to discuss briefly some of these suggestions.

In recovery of tobacco plants from the ring-spot disease, there is apparently a mechanism for limiting virus production to a level considerably below that present in plants during the onset stage of the disease (80). Although the exact nature of the mechanism is unknown, the discovery of the difference in virus concentration led to the formulation of the following hypothesis (80). Ring-spot virus is able to reach its maximum concentration in, and to exert its maximum effect upon, only those cells that are nearly mature at the time of invasion. Invasion of embryonic cells of tobacco plants is not accompanied by maximum increase

in virus nor by severe injury to the cells. Having once been invaded, the embryonic cells become adapted to the presence of virus and maintain an equilibrium with it. Symptoms are produced in tobacco plants just as long as the growing point has not been invaded. Once the embryonic cells become infected, the plant recovers. This hypothesis is supported by the fact that the onset stage of the disease may be prolonged or shortened by exposure of infected plants to good or poor growing conditions (76) which, presumably, increase or decrease the time required for the virus to reach the growing point. Whether or not the hypothesis is correct, it still does not reveal the fundamental nature of the mechanism involved.

Thung (105) has suggested that virus-infected plants, like animals, develop immunizing substances which neutralize or tend to neutralize the virus in the plant. Such substances have not yet been demonstrated. The hypothesis that they may play an active part in acquired immunity from plant virus diseases therefore awaits experimental proof.

A simple explanation for cross immunity in plants may be based on the assumption that certain protoplasmic constituents, such as, perhaps, specific amino acids, are essential for virus reproduction. It is conceivable that one virus in a plant may exhaust the supply of material essential for reproduction of that particular virus and thus render the invaded cell immune from a closely related virus that requires the same material. Other unrelated viruses, however, might require entirely different materials which would not be utilized by the first virus. The cell would, therefore, still be just as susceptible as a virus-free one. Essentially this hypothesis was suggested as a possibility by Kunkel (58), by Köhler (57), by Bawden (5), and by Salaman (86). While the hypothesis may serve to explain the chronic-disease type of acquired immunity, it does not explain the carrier type in which the virus concentration of recovered tissue is considerably lower than that of diseased tissue; it must be inferred that, in this type, either the essential material has not been entirely used up or its production by recovered plants has been sharply curtailed. Furthermore, it has been pointed out by Kunkel (58) that, although the dark green areas of leaves mottled by tobacco mosaic contain less virus than the yellow areas, they are nevertheless immune from aucuba mosaic.

It seems apparent that present theories are inadequate to account for acquired immunity from plant virus diseases. It is possible that some mechanism entirely different from those mentioned is involved. A satisfactory solution to the problem must await further discoveries in plant virus immunity.

COMPARISON OF ACQUIRED IMMUNITY IN PLANT AND ANIMAL VIRUS DISEASES

Plants have not been shown to acquire *passive* immunity from virus diseases. The reasons for this seem fairly obvious. In the first place, plants are not known to develop antibodies or immunizing substances against viruses. Moreover, even if such substances were known, the absence in plants of a circulatory system comparable to that of animals would seem to make it extremely difficult if not impossible to obtain thorough spread of such substances from a single injection in healthy plants. The role of antibodies in animal virus acquired immunity is not well understood. It is possible that their function is only secondary, since an animal may show a solid immunity in the absence of demonstrable antibodies or may be susceptible in the presence of large

amounts of antibodies (118). The apparent absence of antibodies in plant virus immunity should not, therefore, necessarily distinguish between acquired immunity in plant and animal virus diseases.

Acquired immunity from plant virus diseases is, so far as known, of the non-sterile type. In a number of virus diseases of animals, acquired immunity following recovery from disease is accompanied by apparent disappearance of the disease agent; at least in some diseases the virus has not been detected in recovered animals by ordinary methods. Retention of virus in plant tissues that have become immune from virus diseases indicates that the immunity is cellular rather than humoral. Because it appears to be cellular, Salaman (86) suggested that its nature is essentially different from that exhibited by animals. This may, indeed, be true. However, a distinction made solely on the basis of retention of virus is apt to be misleading, for there are many cases of non-sterile acquired immunity in animal diseases. For example, Cole and Kuttner (24) were able to obtain virus from the submaxillary glands of guinea pigs that were immune from the effects of the virus introduced elsewhere in their bodies and to show that the same virus was often lethal for guinea pigs that had not previously been infected. Koch (56) showed that virus was present in the blood of horses as long as 7 years after an attack of infectious anemia. In this case, recovered horses are not completely immune, since they may sometimes suffer a relapse. Theiler (103) has reported that horses frequently carry virus of African horse-sickness for as long as 90 days after recovery. In contagious epithelioma of fowls, virus can be obtained from certain organs as long as 4 weeks after complete recovery from the skin eruption, although the recovered birds have a strong active immunity to cutaneous infection (67, 88).

It has been shown by Traub (107, 108) that mice clinically recovered from choriomeningitis frequently carry virus in their blood for several weeks or months. Such mice have a high degree of immunity, while mice that have never had the disease are always killed by intracerebral injection of choriomeningitis virus. Clinically recovered mice no longer carrying detectable amounts of virus in the blood often show an incomplete immunity to intracerebral injection. Traub concludes that the immunity of carrier mice probably is not due to protective antibodies but that it may be tied up in some manner with infected tissues.

According to Zinsser, Enders, and Fothergill (118), it is probable that, in individuals who have recovered from herpes and have acquired a general immunity from the disease, the virus remains latent in special tissues and gives rise to another attack following injury to certain body cells. Other instances, cited by Zinsser, Enders, and Fothergill, of retention of virus in immune animals are foot-and-mouth-disease virus in hoofs of recovered cattle, poliomyelitis virus in the nasal secretions of a child after recovery from a second attack, virus 3 in a transplanted neoplasm and metastases therefrom in a rabbit that had become immune, vaccinia virus in a rabbit 22 days after establishment of cutaneous immunity, and spontaneous-encephalitis virus in the cords of mice almost a year after recovery.

Recovery from diseases produced in man and lower animals by filterable viruses is, in many diseases, followed by lasting immunity. Because the immunity is lasting, the possibility that it is associated with the persistence of virus has been suggested (84, 117, 118). The failure to demonstrate virus after recovery from

some virus diseases may be due to the presence of antibodies that render the virus noninfectious. That such might be the case is suggested by the tendency of virus to disappear from the blood of rhesus monkeys infected with yellow fever long before the disease has run its course. According to Hudson and Philip (45), virus may be detected in infected monkeys within 12 hours after inoculation and is present in high concentration up to the 5th day following infection. Beginning on the 5th day, the virus decreases in concentration, and it may completely disappear from the blood stream a day or more before the monkey dies from a fatal infection. It appears unlikely that virus actually disappears from the blood before termination of the disease. It seems more likely that virus is still present but is neutralized by antibodies that have developed as a result of the infection. This view is supported by the fact that monkeys inoculated with as much as 5.0 cc. of blood from a 5-day or older case of yellow fever developed mild symptoms and recovered, whereas monkeys inoculated with only 0.5 cc. of the same blood succumbed to a fatal attack, thus suggesting that sufficient antibodies were present in 5 cc. of blood to partially immunize the monkeys against yellow fever.

The situation in equine encephalomyelitis seems to be somewhat similar to that in yellow fever. Although virus may be readily detected during the febrile period, it has never been demonstrated in the blood of horses showing symptoms of the disease. TenBroeck, Hurst, and Traub (102) measured the virus titer in the blood stream of an experimentally infected horse. The virus reached its highest level 3 days before definite symptoms were evident, decreased rapidly, and could not be detected 24 hours before symptoms appeared or thereafter. These workers cite evidence for their belief that this behavior is typical for field cases of the disease.

In view of the facts that have been stated above, there appears to be little reason for assuming that acquired immunity from plant virus diseases is fundamentally different from that which obtains in animal virus diseases. Whether or not such a difference exists can not be told until more is learned of the fundamental nature of the condition in both animals and plants. Some workers (91, 57) have suggested that the term "acquired tolerance" would be more appropriate than the term "acquired immunity" in connection with the phenomena observed in certain plant virus diseases. There is considerable justification for such a viewpoint. The same suggestion might be made for the many incomplete immunities induced in animals. There seems to be no good reason for setting acquired immunity in plants apart from acquired immunity in animals, and it is therefore felt that the latter term should be retained, at least for the present.

SUMMARY

The evidence reviewed in this paper supports the conclusion that actively acquired immunity from plant virus diseases has been satisfactorily demonstrated. In contrast, passively acquired immunity has not been demonstrated. Immunity that follows recovery from certain plant virus diseases is of the carrier type. Cross immunity, or the inhibition of virus development in a plant cell already infected with a closely related virus, may be either of the carrier or chronic-disease type.

There are at least six different virus diseases in which recovery from the disease is followed by immunity from a second attack, namely, tobacco ring spot,

tobacco ring spot No. 2, tobacco streak, and Bergerac ring spot, all in tobacco (*Nicotiana tabacum* L.), sugar-beet curly top in certain races of tomato (*Lycopersicon esculentum* Mill. and *L. pimpinellifolium* Mill.), and potato yellow dwarf in potato (*Solanum tuberosum* L.). The characteristic features of the immunity are similar for all six diseases. Plants recover after an acute attack by production of shoots or leaves which appear healthy or show only mild symptoms of disease, which still harbor virus, and which are refractory to infection with the virus in question but not to infection with unrelated viruses. It was suggested that there may be other plant virus diseases besides those mentioned in which similar recovery occurs, and it was pointed out that the partial recovery exhibited with numerous other plant virus diseases may or may not be expression of an immune reaction.

With respect to cross immunity, it has been shown with numerous groups of viruses that plant tissues invaded by one strain of a virus are protected from infection with another strain of the virus but are susceptible to infection with unrelated viruses. The immunity appears to be closely associated with presence of virus in the immune tissues, since there is no evidence that virus-free tissues of infected plants are immune. The cross immunity reaction has proved useful for differentiation and classification of plant viruses. The reliability of its use for this purpose has been discussed in some detail.

There is at present no basis for determining whether or not acquired immunity from plant virus diseases is fundamentally different from that obtaining in animal virus diseases. The hypotheses that have been advanced to explain the possible mechanism of acquired immunity from plant virus diseases are apparently inadequate.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *1901 East Madison Street, Baltimore, Maryland, U. S. A.*

BRIEF NOTICES

EVOLUTION

FOSSIL ORTHOPTERA ENSIFERA. *Vol. 1, text; Vol. 2, plates.*

By Frederick E. Zeuner. British Museum (Natural History), London. Vol. 1, 15s. Vol. 2, £1. $8\frac{5}{8}$ x $5\frac{1}{2}$; Vol. 1, xiii + 321; Vol. 2, 80 plates; 1939.

It is indeed fortunate that the very fine collection of fossil Orthoptera in the Natural History department of the British Museum has had such an able interpreter as Zeuner.

The order Orthoptera (earwigs, cockroaches, stick insects, locusts, crickets) is not large in number of species but its distribution is world wide. Possibly no small factor in the ubiquity of these insects is that their ancestors got started a long time ago. Geologically the group is the oldest of the winged orders of insects.

"The Ensifera as a separate stock can be traced as far back as the Upper Carboniferous. Their ancestors belong to the Protorthoptera and are closely related to those of the Acridioidea which form the other large suborder of the Orthoptera Saltatoria. This surprising phylogenetic independence of the Ensifera justifies their treatment in a separate Catalogue." Zeuner has been able "to reconstruct the evolution of all the families concerned and to find the probable causes of the divergence of the various stocks."

The textual part concludes with an extensive literature list and a useful index. The illustrations which form so important a part of the report are grouped together in a separate volume and consist of (a) numerous line drawings largely showing wing veination and pattern and (b) photographic reproductions mostly of the fossil forms of Ensifera, many of which have been found embedded in amber.

STUDIES ON THE ICE AGE IN INDIA AND ASSOCIATED HUMAN CULTURES.

By H. de Terra and T. T. Patterson. Carnegie Institution of Washington, Washington, D. C. $6.50 (paper); $7.50 (cloth). $11\frac{1}{2}$ x 9; xi + 354 + 56 plates; 1939.

This report includes studies on the Ice Age cycle in the Himalaya and the Pleistocene history of Stone Age Man in other parts of India. These studies were made from the geologic and archaeologic results of a 1935 expedition to India under the direction of H. de Terra in association with T. T. Patterson and P. T. de Chardin. The five areas in India with which this report is concerned are: (1) Kashmir, (2) Potwar-Indus (northwestern Punjab), (3) Narbada Valley near Hoshangabad and Narsinghpur, (4) Madras, and (5) Sukkur and Rohri, Upper Sind. In addition to a discussion of the Ice Age in southwestern Kashmir, four other subjects are presented, but in lesser detail: the Pleistocene geology and Stone Age cultures in northwest and peninsular India; the Pleistocene in the Narbada Valley of Central India; the stratigraphic and typologic sequence of the

Madras paleolithic industries; and the late Stone Age sites at Sukkur and Rohri on the lower Indus of Upper Sind. This detailed work is an excellent contribution to geologic and archaeologic studies on the Himalayan Ice Age and early Man in Southern Asia. There are numerous text figures and maps and photographic plates. Bibliography, index, and two folding maps are included.

TEXTBOOK OF PALEOBOTANY.

By William C. Darrah. D. Appleton-Century Co., New York and London. $6.00. 8¾ x 6; xii + 441; 1939.

Although many studies have appeared within the last twenty years dealing with fossil plants, no suitable textbook for the beginner has been issued. The author of the present text gives a biological rather than a geological approach to the subject. He assumes on the reader's part a working knowledge of general botany, of the elements of plant anatomy and some knowledge of historical geology. The four main divisions of the book are as follows: I. General principles (4 chapters) —a discussion of geological and biological principles and the paleobotany of coal. II. The paleontological history of the vascular plants (12 chapters)—this begins with the Psilopsida and ends with sections on the origin and geological history of the angiosperms. II. The succession of ancient floras (4 chapters)—Paleozoic, Mesozoic, Cenozoic floras and the origin of existing floras. IV. General results (3 chapters)—fossil thallophytes and bryophytes, concepts of paleobotany and a reasonable phylogeny of vascular plants. Numerous illustrations appear throughout the text and each chapter is well documented. An excellent working index is provided.

GENESIS AND SCIENCE.

By Harold W. Clark. (Obtainable from the author, Angwin, Calif.). 15 cents. 7 x 5; 36; 1940 (paper).

"It is a tragic fact that the great men of the world have refused to see the beautiful truths of creationism, and have turned their attention to the evolutionary interpretation of nature." Mr. Clark believes that inasmuch as the Bible is wholly and literally true, being God's word to man, it must be in perfect agreement with science, which studies God's works of nature. He attempts to reconcile the two by the lopsided compromise of contorting the findings of science to agree with the story of the creation. In two pages the writer breaks down the evidences of evolution from studies of comparative anatomy, embryology, blood tests, and vestigial structures. He claims that all of the rock strata could have been laid down in a very short period of time as a result of wave action during the flood. Not only intelligent biologists, but intelligent theologians as well will find these pages a lot of tommy-rot.

THOUGHTS ON EVOLUTION. *IV. Rejection by American Ethnologists. Anthropological Series of the Boston College Graduate School, Vol. 4, No. 4, Serial No. 16.*

By Joseph J. Williams, S.J. Boston College Press, Chestnut Hill, Mass. Subscription, $3.00; Single copy, $1.00. 9⅝ x 6½; 29; 1939 (paper).

This is a periodical containing two articles. One is a report on recent excavations at Ksar 'Akil, and the other an attempt to prove that American ethnologists have repudiated the theory of evolution. This latter essay is one of a series and perhaps it is not fair to pass judgment upon it apart from its predecessors. The author draws heavily on Boas, Goldenweiser, Lowe, Kroeber, and others to put *Homo sapiens* outside the pale of evolution, but about all he accomplishes is to show that authorities are not agreed as to whether the pleistocene sub-men were ancestors or only collateral relatives of modern man.

GENETICS

CONGENITAL MALFORMATIONS. *A Study of Parental Characteristics with Special Reference to the Reproductive Process.*

By Douglas P. Murphy. University of Pennsylvania Press, Philadelphia. $1.50. 9 x 6; vi + 98; 1939 (paper).

This monograph reports the results of an investigation which had for its main stated purpose to determine whether a higher than expected number of congenitally malformed infants were born in families where such a birth had already occurred. In addition, the author has also examined other factors that might be related to the incidence of congenital malformations, viz.: socio-economic status and health of the parents, age, pregnancy, and puerperal history of the mothers. The material was obtained by selecting from the records of the deaths that took place from 1929 to 1934 in Philadelphia all those certificates stating that congenital malformation was the cause of death. These numbered 1476 but in only 890 instances (884 families) had the diagnosis been confirmed. The family inquiry was concerned with the latter group and all the information desired was obtained for 501 families. With regard to the main objective of the study the findings are interpreted to indicate that in families in which a malformed child has been born the chances of another malformed child being born are 25 times greater than for the general population. Moreover, it was apparently found that the older the mother the higher are the chances of a malformed offspring and the birth of this is usually preceded by a period of relative sterility. No association was discovered between the incidence of malformation and the social status, health, and puerperium of the mother, or the age of father and mother. The author is therefore lead to conclude that "congenital malformations arise solely from influences which affect the germ cells prior to fertilization." This conclusion is acceptable and one to be expected on the basis of the findings of other students of the problem. It should be remarked that, as presented, the results of this investigation are not completely probative. The biometric analysis is weak and the author is apparently entirely oblivious of the fallacies that could arise from the sampling technique employed.

STUDIES ON THE PHYSIOLOGY, GENETICS, AND EVOLUTION OF SOME CLADOCERA. *Carnegie Institution of Washington, Publication No. 513. Paper No. 39, Department of Genetics.*

By A. M. Banta, with the collaboration of Thelma R. Wood, L. A. Brown, and Lester Ingle. Carnegie Institution of Washington, Washington, D. C. $2.50 (paper); $3.00 (cloth). 11½ x 9; x + 255 + 4 folding charts; 1939.

These studies, begun in 1911 and continued to the present, were started during that period when selection was looked upon as the prime mover of evolution. *Cladocera* proved to be an organism well adapted to experiments in such fields. Banta, by using selection, established two races—the first reacting very rapidly to light, the second reacting slowly or not at all.

Closer studies upon this form led to the finding of sex intergrades which proved to be mutational. The effect of environmental conditions upon the sex ratio of the offspring also received much attention. It was found that increasing temperature gave a bimodal curve for male percentages and that these centered at 14°C. and 20°C. Density of population was found to be an important factor in the determination of sex. An isolated mother produced only females. When the maternal density was 8 per culture, 56 per cent of the offspring were males. The evolutionary significance of the findings is discussed.

A bibliography of 202 titles is present. Drawings and diagrams aid in the clarification of the text and a fine index is appended.

BLOOD GROUPS IN AFRICA. *Publication of the South African Institute for Medical Research No. XLIV. (Vol. IX).*

By Ronald Elsdon-Dew. South African Institute for Medical Research, Johannesburg. Free. 10¼ x 7½; 66; 1939 (paper).

This paper is the sixth in a series, published by the South African Institute for Medical Research, and is a continuation of an investigation of the blood groups of the tribes of Africa—the object of the

investigation being to trace the racial history of these peoples (if possible) and place them in their proper order of origin. The present study deals with tribes in East Africa, and tables and charts present a clear reading of their blood grouping and the several gene frequencies. There is also a recapitulation of results previously published, and while no theories of ethnological distribution have been proven, very considerable knowledge has been added to that already gained. This investigation together with those of earlier date should be of special interest to geneticists.

HEREDITY AND SOCIAL PROBLEMS.

By L. L. Burlingame. McGraw-Hill Book Co., New York and London. $3.50. 9 x 6; xi + 369; 1940.

This textbook aims to give students of biology a general view of the significance of the findings of modern genetics in relation to social problems. The first third of the book contains a fairly simple exposition of genetics and its application to the study of the inheritance of physical characters in man. The remaining part, about two-thirds of the book, is concerned with an examination of the evidence on the inheritance of behavioristic and mental traits: criminality, intelligence, mental deficiency, etc. Sandwiched among these is a discussion of population problems and of race. The author has obviously been influenced by the recent pronouncements of the eugenists and it is apparently from such a standpoint that he presents the subject.

PEDIGREES AND CHECKERBOARDS.

By E. Fletcher Barrows. Edwards Bros., Ann Arbor, Mich. $1.50. 10⅝ x 8⅜; 233; 1940 (paper).

Cases in great variety are presented for exercise in the determination (a) from given pedigrees, of the probable genetic make-up of the individuals concerned, and (b) from crosses in which the parental genotypes are specified, of what kinds of offspring and what Mendelian ratios may be expected. The construction of numerous Punnett squares is suggested. All fundamental aspects of modern genetic theory are covered, but no breeding experiments are outlined. This is a manual for desk work only.

THE PRINCIPLES OF HEREDITY. *Second Edition.*

By Laurence H. Snyder. D. C. Heath and Company, Boston and London. $3.50. 8¾ x 5¾; xv + 452; 1940.

The present edition of this excellent text follows closely the organization of the early edition (reviewed Q.R.B., Vol., 10, p. 454) with but few minor changes. A new chapter on giant chromosomes has been added, synthesizing the investigations in this important branch of present day genetics. New illustrations have been added, and the lists of references extended.

GENERAL BIOLOGY

VITALISM: *Its History and Validity.*

By L. Richmond Wheeler. H. F. and G. Witherby, London. 15s. net. 8⅝ x 5½; xii + 275; 1939.

A great amount of painstaking scholarly research has gone into the making of this book, and the result will astonish those who have given only casual thought to the subject. Unfortunately, the title is somewhat misleading as the greater part of the book is taken up with interpretations of the thoughts of past authorities on vitalism, rather than with a consideration of vitalism itself as a living theory. But the book is better than its title.

The average man, if he thinks of vitalism at all, is likely to consider it an essentially modern development—the natural reaction to the materialism of the nineteenth century. But if he reads this book he will learn that not only was Aristotle the originator of the theory, but that the belief was held by practically all subsequent men of science (there were

of course not many of them) down to about the middle of the seventeenth century.

In this century a great many changes took place in the scientific thought of western Europe. The birth of the classical physics of Galileo and Newton naturally gave a mechanical slant to the speculations of natural philosophers. It also helped to drive into permanent oblivion the old belief that the baser metals could be transmuted into gold, by establishing the fixity of the elements. Under a materialistic philosophy this idea of fixity was easily transferred from the inorganic to the organic world, and the doctrine of the fixity of species was the result. Sporadic attempts to overthrow this doctrine were made at odd intervals by Erasmus Darwin, Lamarck, Robert Chambers and others, but it was never seriously challenged until the publication of the *Origin* by Charles Darwin in 1859.

To list the authorities whose contributions to the philosophy of vitalism are expounded by Wheeler from Aristotle and Galen to Jeans and Eddington would be to compile an encyclopedia of biography. Certainly not many have been missed. Yet the present reviewer puts down the book in a somewhat confused state of mind. This is partly due to inadequate documentation. There are practically no footnotes. Editorial comments are inserted parenthetically, thus interrupting the continuity and so adding to the difficulty of reading. The bibliographies at the end of each chapter make no pretense to completeness—if every citation in the text were listed the bibliographies would be several times their present length, and the usefulness of the book would be enhanced proportionately.

Another source of confusion is the use of technical terms to mean different things at different times. For instance the term "orthogenesis" is sometimes used to mean development past the optimum point for usefulness to that of danger—and at other times to mean teleogenesis. Also, the word "mechanism" is used as if synonymous now with machine, now with automaton. But this is not so much the author's fault as of those he quotes.

But despite this confusion there is much in the book to be commended. The index is quite exhaustive and there is great clarity of expression throughout the work. Perhaps the reviewer may be pardoned for closing with a quotation from the work that he finds enlightening:

> Vitalism and mechanism are the only two types of theoretical biology yet devised and both involve the analogy of a humanly constructed machine. Vitalism allows for a mechanic. Mechanism forgets that a mechanic is essential and only achieves being materialistic by omitting the 'psychological origin' of the machine.

DER KAMPF UMS DASEIN. *Eine biologisch-mathematische Darstellung der Lebensgemeinschaften und biologischen Gleichgewichte. Abhandlungen zur exakten Biologie, Heft 1.* *By Umberto D'Ancona. Translated by Ludwig Holzer. Verlag von Gebrüder Borntraeger, Berlin.* RM. 15. 10 x 6½; x + 196 (paper).

The first portion of this work treats of the main contributions by men who have added to our knowledge of the behavior of biological populations. The equations of Lotka regarding interspecific relationships are dealt with. The fundamental concepts of the theory of Volterra concerning biological populations are extensively presented. The Verhulst-Pearl logistic curve is given and some of the experimental work of Pearl upon *Drosophila* is described. Other authors whose observations are noted include: Darwin, Moebius, Celli, Friederichs, Elton, and Gause.

The second portion of the work is concerned with principles of biological populations which may be drawn from the works of the foregoing scientists. At first glance the mathematics used and the conclusions drawn therefrom, may appear rather heavy for the biologist. The writer of the work, however, states: "Es [the book] handelt sich hier also nicht um eine mathematische Arbeit für Mathematiker, sondern um eine biologische für Biologen, in welcher die Mathematik als gedankliches Hilfsmittel dient."

The volume contains many graphs which amplify and clarify the text. An extensive bibliography is presented.

CARNEGIE INSTITUTION OF WASHINGTON. *Year Book No. 38, July 1, 1938–June 30, 1939. Carnegie Institution of Washington, Washington, D. C.* $1.00 (paper); $1.50 bound. 10 x 6¾; xxxii + 394; 1939 (paper).

The first part of this report is concerned with official matters such as lists of officers and trustees, staff investigators, research associates connected with other institutions, etc. The President, Mr. Vannevar Bush, gives a general report on the present status of research work in the various branches of the Institution and outlines some of the problems that are either in the process of being investigated or are to be taken up in the future. There follow separate and more detailed departmental reports under the following headings: astronomy, terrestrial science, biological sciences, and historical research. To those who are familiar with the publications from the biological sections—both plant and animal—these reports are of especial interest as the reader obtains an understanding of the general scope of the work that is in progress. Also of interest to the biologist are those sections dealing with historical research where the first decade's accomplishments are reviewed, including the very fine work in the Maya field, the reports dealing with genetics, nutrition, and paleontology, early man, and historical geology.

ORGANISMEN UND UMWELT. *20 Vorträge. Zweite Wissenschaftliche Woche zu Frankfurt A.M. 28.–30. Juni, 1939. Edited by R. Otto in collaboration with K. Felix and F. Linke. Verlag von Theodor Steinkopff, Dresden and Leipzig.* RM. 11.25. 9¼ x 6¼; xiv + 275; 1939 (paper).

The principal theme of the papers presented was the relationship between the organism and its environment. Both plant and animal research were used as a basis for the discussions. Some of the subjects treated were: environment and heredity; race and environment; the importance of photodynamic phenomenon in biology; plants and radiation; influence of the radioactive environment upon the organism; the importance of frail elements in the development and association of plants; specific immunity against microorganisms. Each talk was followed by a general discussion which is placed at the end of each report.

There are many illustrations and a good index.

THE SEASONS AND THE FARMER. *A Book for Children. By F. Fraser Darling. Drawings by C. F. Tunnicliffe. The Macmillan Co., New York; The University Press, Cambridge.* $2.25. 8¾ x 6¾; vii + 72; 1939.

The belief that many city children never get to see or know much about the farm has prompted Darling to write this somewhat romantic account of the farmer, his crops, his animals, and his work the year around. The subject matter and illustrations are drawn exclusively from British sources, and in consequence, the book will be of reduced value for American consumption. The author's consistent use of the words wheat and corn interchangeably when obviously referring to wheat would be extremely confusing to an American child. Many of the homely methods of English farming would be amusing to our machine-minded American farm children. However, for English consumption, the little volume will undoubtedly serve its purpose well.

THE WORLD UNDER THE SEA. *A Concise Account of the Marine World. By B. Webster Smith. D. Appleton-Century Company, New York and London.* $3.00. 9 x 6; 230; 1940.

Because simpler studies of oceanography in the language of the layman are rare, the author has written this small book to fill the gap by setting before the reader "a plain and straightforward account of oceanic phenomena, followed by a brief and general survey of marine life." The volume includes chapters on submarine earthquakes and volcanoes, oceanic currents and tides, and a description of the ocean floor as well as accounts of many forms of marine life from sharks and rays

to marine plants and minute animals. It is well illustrated with photographs and drawings and there is an adequate index.

BIOLOGICAL DRAWINGS *with Notes. Parts 1 and 2.*

By Maud Jepson. Preface by H. Graham Cannon. Chemical Publishing Co., New York; John Murray, London. $2.00. $11\frac{3}{4}$ x $9\frac{3}{4}$; Part 1, iv + 60; Part 2, iv + 60; 1939.

This splendid collection of biological drawings can be used to practical advantage by students in courses where the time is limited. They should be of great value to the student in the laboratory, furnishing, as they do, clear-cut concepts of botanical and zoological structures. The author has included numerous notes in addition to those used for labelling purposes. Parts I and II are bound together but have separate indices.

HUMAN BIOLOGY

CAPITALISM THE CREATOR. *The Economic Foundations of Modern Industrial Society.*

By Carl Snyder. The Macmillan Co., New York. $3.75. $9\frac{1}{4}$ x $6\frac{1}{4}$; xii + 473; 1940.

During the last century mystics and humanitarians in general have greatly intensified their attacks against the capitalistic system, and in the last two decades, particularly the foundations of free trade have been badly shaken, if not destroyed. Today, in fact, it is a rather risky business to defend the system advocated and taught by Adam Smith. Therefore the author is to be greatly admired for his courage in making this panegyric of capitalism. The theme that Snyder develops and embroiders is that capitalism is an integral aspect of our ways of living and that because of it this country especially has advanced to a high social level. Without capitalism, without the right of private property and profit the great industrial progress of this country would never have been achieved. The author goes to great lengths, employing a mass of facts and figures, to demonstrate the truth of this view. The evidence in its favor is formidable and none but fools or knaves could deny it. However, is it with respect to this point that many argue for a modification or the overthrow of capitalism? As Pareto, on whom the author leans heavily, pointed out the problems of *applied* economics involve a strong non-rational element—that of so-called humanitarianism—and it is on these grounds that communists, socialists, and new-dealers have made what appears to be successful headway against the principles of liberal economy. This book has apparently been written for the layman and it is one of the clearest and most complete expositions of capitalistic principles that has appeared in many years, besides containing an adequate interpretation and summary of the economic history of this country.

HOW CAME CIVILIZATION?

By Lord Raglan. Methuen and Co., London. 6s. net. $7\frac{1}{4}$ x 5; xi + 191; 1939.

The author's belief is that the human race does not possess an instinct or natural tendency towards progress but that civilization is a rare manifestation of the sporadic creative efforts of a few of its "citizens." In line with this belief the author reasons that the so-called "primitive" devices which scientists believed primitive peoples to have developed were invented once and once only and in one place, and from that place were diffused to other areas. The author believes that the theory of multiple inventions is a fallacious one.

> . . . .that progress has always been rare and sporadic; and that today there is, outside Western civilization, nothing but stagnation or decay.
>
> So far as we know, no savage has ever invented anything, and the researches of experts lead them to the conclusion that all the elements of civilization, including agriculture and the domestication of animals, the use of metals, bows, boats, pots and wheels, were developed once only, each at some one spot, and thence diffused to where they are now found.

The author shows that the invention of the bow and arrow was not a simple

invention but a complicated one involving at the least, nine steps in the making. This complexity gives one reason "for doubting whether it was invented independently by primitive savages in various parts of the world." *How Came Civilization* presents a strong if not wholly convincing argument in favor of the diffusionist school of thought. Bibliography, index and illustrations are included.

ALL TOO HUMAN. *An Unconventional Autobiography.*

By Owen Berkeley-Hill. Peter Davies, London. 8s. 6d. net. $7\frac{3}{4}$ x $5\frac{3}{4}$; [8] + 384; 1939.

General speaking all autobiographies are interesting and this volume is certainly no exception to that rule. The author is an eminent psychiatrist who stems from the distinguished English family that included among its members Sir Rowland Hill, the originator of Penny Postage in England and of modern postal systems generally.

Berkeley-Hill was educated at Oxford, Göttingen, Nancy, and London. Soon after the turn of the century he entered the Indian Medical Service. In due time he married a Hindu wife of the Tiyyan caste. This proved in the event to be an enduring and happy marriage, in spite of the social difficulties it entailed for the partners to it and their children.

One of the things that makes this an extraordinary autobiography is the author's frankness about his own sex life, to which one whole chapter is devoted to say nothing of frequent references to the same subject through the book. The following lines constitute the only preface the book has: "This book has been written at the express desire of my children. What they will think of it and of me if they ever read it I cannot even guess. However, I have done my best to write the story of my life, most of which, as Sydney Smith said of his own, has been 'like a razor, either in hot water or a scrape'."

It seems reasonably safe to say that no other father ever told his children, through the medium of a published book, quite so much about his sex experiences and attitudes.

Altogether a remarkable book thoroughly indexed.

THE RACES OF CENTRAL EUROPE. *A Footnote to History.*

By G. M. Morant. Preface by J. B. S. Haldane. George Allen and Unwin, London. 5s. net. $7\frac{1}{4}$ x $4\frac{3}{4}$; 163; 1939.

The purpose of the study reported in this book is "to discover how far the physical evidence relating to the peoples of Central Europe leads to conclusions regarding 'race' that are in accordance with those derived from cultural data and primarily from language." In particular, the author wishes to bring to the attention of the general public the fallacies of the concept of race as preached by certain German writers. He therefore examines some of the available data on stature, the cephalic index, skin, hair and eye color, hair form, and blood groups of samples of German, Czechoslovakian, Austrian, Polish, and Hungarian populations. As is well known, for some physical traits these national groups do differ in terms of the average measure. But due to the variability within each group, not all the individuals of one group are distinguished relative to these traits from all the persons of the other groups. Moreover, the author emphasizes that in passing from one country to another geographically contiguous the change in the measure of the physical characteristics is gradual and not abrupt as is the change in language and culture. This point is questionable since it needs proof that there is a sudden transition in the language actually spoken by the inhabitants on the two sides of a boundary line. The author closes with a plea for a greater popular diffusion of anthropological knowledge so that ideas such as those of racial purity and superiority will not be easily accepted by the general public. Every human biologist will certainly associate himself with this plea.

INDIANS OF THE UNITED STATES. *Four Centuries of Their History and Culture.*

By Clark Wissler. Doubleday, Doran and Co., New York. $3.75. 9¼ x 6¼; xvi + 319 + 18 plates; 1940.

This is the first of a special series of science books prepared for the general public under the auspices of the American Museum of Natural History. In this volume Wissler describes the Indians who inhabited North America in 1492 and when possible traces their movement to the present day. The book is divided into three parts and in the first, by way of introduction, the author summarizes the evidence that has been uncovered about prehistoric Indians and the deductions and conclusions to which such findings have led. The substance of the book is contained in the second part. For each of the major ethnic groups into which the North American Indians can be segregated a detailed account is given of the physical characteristics, political organization, mores, culture, geographic distributions and the history, particularly in relation to the wars with other Indians and with the white man. These accounts are made more interesting by the inclusion of short biographical sketches of the leading historical personalities of each group. In the third part the author discusses the consequences of the contacts between the white man and the Indian (mostly bad for the latter) and the future of the Indian in this country. For the purpose for which it has been prepared the book is excellent. The author has succeeded in giving a clear portrayal of the Indian and one that is about as accurate as could be possible without recourse to pedantry.

THE BAIGA.

By Verrier Elwin. With a Foreword by J. H. Hutton. John Murray, London. 30s. net. 8¾ x 6; xxxi + 550 + 54 plates; 1939.

The Baiga were aboriginals of Central India and are now found mainly in the Eastern Satpura Mountains. They number about 40,000 souls and apparently have not yet been much influenced either by the Hindu or the Western civilization. The author has lived among them for almost a decade, having established schools, a dispensary, and a leper home in their country. In this report of his observations he describes fully their mode of living, customs and beliefs. The Baiga are not far above the hunting cultural level. Their daily life appears to be centered around the simple satisfaction of the physiological urges. The importance given to sexual manifestations is noteworthy and the author discusses their sex behavior at length and with what seems to be a more profound insight than most anthropologists possess. In addition to chapters on the social organization, jurisprudence, mythology, magic, healing art and folklore of the Baiga this book contains a very interesting one on the kinds of dreams reported by some of them. Particularly illuminating are the life-stories of some of the notable persons of the tribe. This book, so rich in authentic information, will be a source of reference for studies on numerous aspects of social behavior.

ECUADOR THE UNKNOWN. *Two and a Half Years' Travels in the Republic of Ecuador and Galápagos Islands.*

By Victor Wolfgang Von Hagen. Oxford University Press, New York. $3.50. 8½ x 5½; 296 + 31 plates; 1940.

To recommend this thoroughly satisfying "travel" book is indeed a pleasure. It is a record of adventurous traveling combined with scientific observation of areas which have previously been visited but seldom described so well. The author, an entomologist, and his wife, a botanist, traveled in the high Andes, and on the sea and river levels of Ecuador to the picturesque cities and the upper Amazon territory. They journeyed as collectors for museums, as scientific observers, and as photographers—so the book is full of vital information. The experience of going to the native habitat of the South American condor, of lassoing two of the great birds and sending them back to the zoo in Memphis is enough to compensate the authors for all hardships endured.

But the main purpose of the expedition was to visit the Galápagos to make criti-

cal observations of changes that had occurred since Darwin's historic voyage one century earlier in 1835. A comparison of data of the two periods is presented with an account of the erection, on these islands, by the author and his wife, of a statue of the evolutionist. The book is well illustrated with photographs by the author. There is an index of eight pages.

A Doctor without a Country.
By Thomas A. Lambie. With an Introduction by Howard A. Kelly. Fleming H. Revell Co., New York, London and Edinburgh. $2.00. 8 x 5½; 252; 1939.

After many hardships, the missionary doctor accompanied by his wife and small children succeeded in crossing the Anglo Sudan into Abyssinia, where Addis Ababa eventually became the center of his activities. If one discounts the religious fervor that pervades the entire work there still remains a large fund of highly interesting information about the customs and beliefs of the natives, and about the animal life and vegetation of the country. Only Ethiopian citizens could hold title to missionary property in Ethiopia, so in 1934, at the personal request of Hailie Selassie, Dr. Lambie renounced his allegiance to the United States in order to become an Ethiopian citizen. Shortly after came the Italian invasion, with the consequent expulsion of his mission from Ethiopia. However, Dr. Lambie regards seeming defeat as a stepping stone to a greater and an ultimate triumph in that the tragedy of Ethiopia may lead to the spread of the Gospel in the Egyptian Sudan, where he now plans to return.

Cherokee Cavaliers. *Forty Years of Cherokee History as Told in the Correspondence of the Ridge-Watie-Boudinot Family.*
By Edward E. Dale and Gaston Litton. University of Oklahoma Press, Norman. $3.00. 9 x 5¾; xxiii + 319 + 7 plates + 1 folding chart; 1939.

An important story well told, without prejudice, this book deals with the successive evictions of the Cherokees from their expulsion from their original home in Georgia to their final settlement in Oklahoma. It is not a story in which white Americans can take pride. The leaders of the Cherokee nation had intermarried with the whites to a great extent and their families were divided by the evictions. The story is told in 199 different letters published for the first time, written between 1832 and 1872 by various members of the related Ridge, Watie, and Boudinot families to each other.

The Cherokees were the most intellectual and the most highly cultured of all the aboriginal inhabitants of the United States. They were the only ones to develop a phonetic alphabet. They were the first to publish their own news magazines. The letters selected for publication here came from a collection of several thousand discovered in an Oklahoma farmhouse several years ago. From them we get the Indians' side of the story. The work is a scholarly presentation, thoroughly indexed and documented.

Frontier Doctor.
By Urling C. Coe. The Macmillan Co., New York. $2.50. 8 x 5½; ix + 264; 1939.

The perseverance required by the "Doc" to meet hardship and to cope with ignorance and superstition among the settlers of our last frontier is realistically portrayed by Dr. Coe in this interesting little novel. The story is essentially an autobiography of the author for the years 1905 to 1911, and represents the diary he intended to keep (but never had time to) when he went to the little town of Bend, Oregon, to begin his medical career.

Still quite green from medical school, Dr. Coe soon found himself amputating limbs with a meat saw, reducing fractures by many ingenious methods, pulling teeth with pliers, and delivering babies by the dozens everywhere. Although the author sticks pretty close to the story he has to tell, he digresses now and then to take a few mild pokes at socialized medicine, and insists that individualism is the foundation of medicine, as well as all other institutions in our Democracy. For enter-

taining reading, we heartily recommend *Frontier Doctor*.

SIR JOHN FRANKLIN'S LAST ARCTIC EXPEDITION. *A Chapter in the History of the Royal Navy.*

By Richard J. Cyriax. Methuen and Co., London. 12s. 6d. net. 8½ x 5½; xviii + 222 + 3 folding maps; 1939.

Here is a scholarly presentation of completely authenticated data regarding early British exploration in the Arctic. Expeditions previous to Sir John Franklin's last voyage are briefly outlined in order to give the historical background of this British search for the Northwest Passage. The detailed account includes a description of the painstaking preparation, and of the final sailing of H. M. ships, Erebus and Terror, in May 1845, under the command of Sir John Franklin. These vessels were the first to go into the Arctic equipped with steam engines, auxiliary to the sails, and in every possible way the latest devices and methods were used to insure the success of the voyage of discovery. But the outcome, as is well known, was a great national tragedy.

The full documentation of the text adds greatly to the interest of the reader, especially as many of these notes are given to the public for the first time. There are maps, appendices and brief biographies of the junior officers of the Erebus and Terror, as well as a six and a half page index.

ANTHROPOMETRIC OBSERVATIONS ON THE ESKIMOS AND INDIANS OF LABRADOR. *Anthropological Series, Field Museum of Natural History, Volume 31, Number 1. Publication 462.*

By T. Dale Stewart. Material and Data Collected by William Duncan Strong. Field Museum of Natural History, Chicago. $1.75. 9½ x 6¼; 163 + 16 plates; 1939 (paper).

The early pages of this publication are devoted to a discussion of the difficulties encountered in the study of Eskimo populations, particularly the problems of racial admixture and physical changes due to altered diet. Following this is a review of the theories of Eskimo and northern Indian migrations and the origin of the various cultures. The anthropometric data presented have a three-fold division—measurements on prehistoric and recent skeletons, on living Eskimos, and on living Indians—the last mentioned material being so meager as to have but little value. Mean values are given in sixty-four tables, while individual measurements are presented in the several appendices. The figures show that in prehistoric times the Labrador and Greenland Eskimos bore the closest skeletal resemblances, being considerably shorter than those of the Thule culture. Brief accounts are given as to population changes during the past century, longevity, and racial intermixture.

FURS TO FURROWS. *An Epic of Rugged Individualism.*

By Sydney Greenbie. The Caxton Printers, Caldwell, Idaho. $3.50. 9 x 6; 413 + 30 plates; 1939.

This book tells the story of the important years in American pioneering history and the men who made it—the fur trappers—who, according to the author, were always some 500 miles ahead of the army and missionaries. Its interest is primarily centered in the thirty to forty years following the Louisiana Purchase and the acquisition of the territory west of the Mississippi. The author writes with interest and understanding of such notables as John Colter, John Jacob Astor, Manuel Lisa, the great American character Kit Carson, and other early Americans. Several chapters are devoted to the Navajo and Pueblo Indians and their customs and crafts. Dr. Carl P. Russell furnishes in the appendix a chronological outline of the history of American fur trade from 1497 to the present. A long and complete bibliography and index are included and the volume is well illustrated with photographs of Indians and reproductions of historical paintings.

NEW GUINEA EXPEDITION. *Fly River Area, 1936–1937.*

By Richard Archbold and A. L. Rand. Photographs by the Authors and L. J. Brass, G. H. H. Tate, M. J. Healy and L. A. Willis. Robert M. McBride and Co., New York. $3.50. 10 x 7¼; xviii + 206 + 1 folding map; 1940.

The second expedition of the authors into the little known Fly River region of New Guinea justly warrants the praise given it in the Foreword by Roy Chapman Andrews. If nothing more had come from the expedition than the trip, it would have been entirely successful in that it revolutionized the method of exploration into jungle country. The method was simply that of using an airplane to drop parachute loads of supplies at the various camp sites along the route of exploration, thus avoiding the necessity of using countless natives to pack the supplies through the dense jungle regions. The text is well written in a clear and interesting style, and is supplied with an index and an abundance of photographs and maps.

DOCTOR'S OFFICE.

By Vincent Tothill. With a Foreword by Owen Rutter. Blackie and Son, London and Glasgow. 7s. 6d. net. 7½ x 5¼; vi + 288 + 8 plates; 1939.

Of the deluge of books by and about doctors which have almost drenched the literary horizon of late, the present volume is perhaps noteworthy only because of its locale—the island of Trinidad. From the windows of the doctor's office and through the eyes of the doctor himself, we get a glimpse of various and sundry aspects of life in this British New World possession. Dr. Tothill gives us his impressions of the natives of the island and how they live, Trinidad society, missions and their methods, education in Trinidad, the medical service, and something about Trinidad's possible future. The author is entirely devoid of any color complex and his years of experience, both as medical officer to a large sugar estate and as a private practitioner, have given him valuable inside information as to conditions on the island. Dr. Tothill's frankness and straightforwardness add a pith and pungency to the book which may leave a bad taste in the mouths of some of his readers.

CHARITY AND THE STRUGGLE FOR EXISTENCE. *The Huxley Memorial Lecture for 1939. Reprinted from The Journal of the Royal Anthropological Institute, Vol. LXIX, Part II, 1939.*

By R. R. Marett. Royal Anthropological Institute, London. 2s. net. 11 x 8½; 13; 1939 (paper).

This rather rambling and poorly organized lecture about a problem of compelling and perennial interest to philosophically minded students of human evolution finds its end point in the following words:

> I therefore conclude, without exceeding my anthropological range, that in general our ethical policy has been sound all along, though here and there we have had to drop various habits by the way. But Charity, as I have contended throughout, can never grow obsolete. It is part of the permanent endowment of the race, seeing that Charity and Justice are as the heart and the head—with, perhaps Holiness as the soul—of the whole evolutionary movement to which our nature is subject.

Marett contends that charity has its evolutionary origin in mother-love. Justice is thought to be the contribution of the father to the moral life of mankind, and to find its "ultimate affinities with male violence and the lust for power as typically displayed in sex-rivalry."

Altogether we cannot regard this as a particularly important contribution.

TWO MEN IN THE ANTARCTIC. *An Expedition to Graham Land 1920–1922.*

By Thomas W. Bagshawe. With a Foreword by Frank Debenham. The Macmillan Co., New York; The University Press, Cambridge. $3.75. 8½ x 5½; xxi + 292 + 19 plates + 1 folding chart; 1939.

Living in a shack made of packing boxes and an old boat hull, two young men spent a year on the coast of Graham Land. This is the story of the hardships encountered during their isolation. However, the adventure was not without its compensa-

tions and the pleasures and trials alike are related in a manner which is entertaining and often quite amusing. The final quarter of the book is devoted to detailed meteorological and tidal observations, and to descriptions of the activities of whales, seals, and various birds. The men were transported to and from their base by whaling vessels, and the account of the whaling industry is of particular interest. The volume is well illustrated and indexed.

NEW ENGLAND COMMUNITY STATISTICAL ABSTRACTS. *Social and Economic Data for 175 New England Cities and Towns. Prepared for the Industrial Development Committee of the New England Council.*

Compiled by Ralph G. Wells and John S. Perkins. Bureau of Business Research, Boston University College of Business Administration, Boston. $3.50. 11 x 8½; 15 + [350]; 1939 (paper).

This book is a collection of statistical data from 175 New England cities and towns. The information contained is primarily for the benefit of manufacturers and business men who may seek new locations and extensions of their operations, and are thus enabled to compare the relative advantages of the different communities of New England for their purposes. These statistics also contain much information useful in further studies on population and economics. The data compiled cover population (native and foreign born), municipal finances (tax rates, bond indebtedness, total property values, etc.), distribution of employment, vital statistics, housing data, educational facilities and other information, grouped so compactly that desired tables may be easily found. The statistics appear to be sound and reliable.

POPULATION. *A Problem for Democracy. The Godkin Lectures, 1938.*

By Gunnar Myrdal. Harvard University Press, Cambridge; Oxford University Press, London. $2.00. 7⅜ x 5⅛; xiii + 237; 1940.

The Swedish investigator who is the author of this book believes that the population problem is the crucial problem of democracy. He points out that America has the unique strategic advantage—if only it can be capitalized—that this problem will mature to acuteness a couple of decades later than in some of the older democracies of northern and western Europe, among them his own. In a general and non-technical way he discusses political attitudes in the population problem, and the economic effects of population trends in western democratic industrial society, using Sweden as his point of reference.

MIGRATION AND SOCIAL WELFARE. *An Approach to the Problem of the Non-Settled Person in the Community.*

By Philip E. Ryan. Russell Sage Foundation, New York. 50 cents. 9 x 6; vi + 114; 1940 (paper).

An interesting study of the migratory population of the United States. It tells us about the different groups of people who move from one part of the country to another, and gives their reasons for so doing. It also gives a fund of information about the social and financial problems that states and communities have to deal with in the effort to care reasonably for this large body of transients. Mr. Ryan seems to think the nearest approach to a satisfactory control of the conditions of life surrounding the non-resident population would be through concerted action of all state and local agencies with government leadership.

POPULATION CHANGES IN THE RIO GRANDE GLAZE-PAINT AREA. *Archaeological Survey. Technical Series, Bulletin No. 9.*

By H. P. Mera. Laboratory of Anthropology, Sante Fe, New Mexico. $2.00. 10¾ x 8¼; 41 + 23 maps; 1940 (paper).

In central New Mexico, in the river valley both north and south of Albuquerque, lived populations characterized by common types of pottery production. The movements and shifts of these populations

from the middle of the 14th century to the beginning of the 18th have been the subject of the author's study for nearly ten years. The distribution of certain archeological objects generally accepted as indicators of the presence or absence of these people has been taken as evidence of changes in their centers of population. Warfare seems to have been the ultimate incentive to movement in every case.

REFUGE IN THE ANDES.

By Rudolph Messel. John Lane the Bodley Head, London. 10s. 6d. net. 8½ x 5½; 285 + 16 plates; 1939.

A group of German refugees had been settled in Colombia, South America, and apparently something had gone wrong with the Colony. This is the story of the author's journey from London to that settlement in an effort to clear up the difficulty. In many ways the book reads like a novel, having a genuine villain who is the personification of the "clutching hand of the Gestapo in the Andes." The hero (the author) of course comes out victorious, and looks forward to the time when the principles which he inaugurated in the colony will dominate the entire organization of South America. The book is entertainingly written despite the vast quantities of political propaganda which it contains. Readers in the United States will find the references to this country highly amusing.

JOURNEY TO THE WORLD'S END.

By Hakon Mielche. William Hodge and Co., Edinburgh, London and Glasgow. 12s. 6d. net. 8¾ x 6⅛; [12] + 297 + 16 plates; 1939.

This is an excellent example of the right way to write a travel book. The author is not a scientist, and there is very little strictly scientific description in his work. He simply got tired of the monotonous sort of life he had been living and went to Cape Horn because that was the most remote part of the world he could think of. The writer has great powers of description and a keen sense of humor, with the result that he has produced a work of universal interest, that holds the attention of the reader just as firmly when reporting the life of the night clubs of Magallones as when describing the flamingoes and ostriches of Tierra del Fuego.

There is no authority, however, for combining the Spanish form of the Christian name of the circumnavigator with the Portuguese form of his surname thus: Fernando de Magelhaes. The Portuguese form of Fernando is of course Fernão. But good books are not wrecked by such details.

THREE GENERATIONS. *The Story of a Colored Family of Eastern Tennessee.*

By Charles W. Cansler. (Obtainable from the author, 1805 Brandau Ave., Knoxville, Tenn.). $1.25. 8 x 5½; viii + 173; 1939.

This book endeavors to trace the changes in the social status of Negroes from *ca.* 1831 to the present. The accounts of the first and second generations are concerned mostly with the position of the slave and the free Negro just before and during the Civil War. The material regarding the third generation is chiefly autobiographical. The dominating thought of the book appears to be an appeal to Negroes to acquire more education, support Negro schools, and unite into organizations in order to elevate the position of the Negro in society. An interesting contribution.

PREHISTORY IN HAITI. *A Study in Method. Yale University Publications in Anthropology Number 21.*

By Irving Rouse. Yale University Press, New Haven; Oxford University Press, London. $2.50. 9¾ x 7; 202 + 5 plates; 1939 (paper).

The author presents a new systematic technique for historical reconstruction in archaeologic research. The scheme is applied to a reconstruction study of the prehistory of the Ft. Liberté region, Haiti. The Ft. Liberté artifacts were obtained by Dr. F. G. Rainey and the writer during a field trip to this region. Included in this

monograph are numerous photographs of the Ft. Liberté artifacts, distribution tables, maps, and bibliography.

ARQUIVOS DE MEDICINA LEGAL E IDENTIFICAÇÃO. *Publicação Oficial do Instituto de Identificação, Ano IX–N. 17.*

Published under the direction of Leonidio Ribeiro. Imprensa Nacional, Rio de Janeiro. 9¼ x 6½; xxiii + 486 + 20 plates; 1939 (paper).

In July, 1938, the first Latin-American Congress on Criminology met in Buenos Aires. This volume contains the addresses, papers, and case reports presented at these meetings. Most of the papers deal with the legal and administrative aspects. Of interest to biologists and medical men are the two studies of L. Ribeiro, one on juvenile delinquency and the other a morphological study of a group of Negro criminals.

ZOÖLOGY

A BIBLIOGRAPHY OF BIRDS. *With Special Reference to Anatomy, Behavior, Biochemistry, Embryology, Pathology, Physiology, Genetics, Ecology, Aviculture, Economic Ornithology, Poultry Culture, Evolution, and Related Subjects. Part 1, Author Catalogue, A to J, Publication 442; Part 2, Author Catalogue, K to Z, Publication 457.*

By Reuben M. Strong. Field Museum of Natural History, Chicago. $11.00 for Parts 1 and 2. 9½ x 6½; 937; 1939 (paper).

The enormous amount of literature that has accumulated in ornithology makes this bibliography a valuable asset to those working on birds. The subtitle indicates the subject matter covered. Taxonomy and distribution have not been stressed, although important publications in this field have not been omitted. Paleontological titles preceding the appearance of Lambrecht's catalogue are included. The year 1926 was originally set as the limit of the literature covered, although later references have been added, but not so comprehensively. In other fields the compiler has had to use his own judgment on the inclusion and exclusion of references, an attempt being made to select only those of value or from an accredited source. However, very few omissions were made with the older literature. In many cases the library in which the reference was found is appended—a valuable bit of information that will save many an hour of fruitless searching. An extremely important and valuable addition to ornithological literature.

POULTRY PRACTICE.

By Leland D. Bushnell, with the collaboration of Edwin J. Frick and Marvin J. Twiehaus and others. Veterinary Magazine Corp., Chicago. $1.00; in lots of 25 or more, 80 cents. 10 x 7; 160; 1940.

The recognition of the poultry industry as a billion-dollar business and the realization of the unnecessarily high mortality among both young and laying stocks of fowls have stirred numerous groups of investigators into activity. The present volume of 34 papers by nearly as many authors, gives a summary of the research to the present time, much of which has been carried out at the Regional Poultry Research Laboratory at East Lansing Michigan.

The articles deal with the anatomy and the physiology of the fowl, as well as with the symptoms, diagnosis, etiology, cause, and in many cases, the cure, for numerous common diseases and pathological conditions. The most startling fact is that in many cases, even though the causes and the diagnosis of a disease are perfectly well known, there is as yet no reliable method of treatment or cure. A constant note of warning for poultrymen is sounded against home diagnosis and treatment of serious poultry diseases, and an attempt is made to show the necessity of calling in a well-trained veterinarian for proper diagnosis and treatment. The short bibliography and index will serve the volume well in the hands of the poultryman, the research worker, and the veterinarian.

PROCEEDINGS AND TRANSACTIONS OF THE LIVERPOOL BIOLOGICAL SOCIETY, *Volume LII. Session 1938–1939.*

Edited by R. J. Daniel, with the cooperation of S. T. Burfield and W. S. Laverock. University Press of Liverpool. 1 Guinea. 8½ x 5⅜; ix + 80 + 2 folding tables; 1939.

This report includes two papers which will be of interest to the student of fish migration. (1) Some notes on Irish Sea plaice—additional data derived from material collected at the Lancashire Sea-Fisheries Laboratory in the University of Liverpool during the period 1908–21 and first reported on in 1921. This material, which is concerned with the age, sex ratios, and distribution of fish during the different age periods, shows that the females generally leave the nursery when three years old and do not arrive at the spawning ground until four years old, while the majority of the males migrate directly to the spawning ground. (2) Salmon of the Cheshire Dee, 1937 and 1938. This is the first of a series of investigations (covering a 5-year period) on the annual adult salmon populations of the Cheshire Dee. Many tables exhibit data for both of these papers. Graphs, diagrams and reference lists are included.

THE LARVAL TREMATODA FOUND IN CERTAIN SOUTH AFRICAN MOLLUSCA: *With Special Reference to Schistosomiasis (Bilharziasis). Publication of the South African Institute for Medical Research No. XLII (Vol. VIII).*

By Annie Porter. South African Institute for Medical Research, Johannesburg. Free. 10¼ x 7½; 492 + 83 plates + 1 map; 1938 (paper).

This very fine survey of the larval trematodes of South Africa contains, aside from the systematic descriptions, much general information concerning geographical distribution, morphology of cercariae (final larval stage of the worms), infestation of molluscs, man and some vertebrates, life cycle of a human schistosome, etc. The vast bulk of the work was done with living material. It was found that some cercariae only emerged from the snails during relatively restricted times (6 A.M. to 7 A.M., others at 12 midnight to 2 A.M., and these usually were dead by 6 A.M.), but others passed out during all hours of the day. A complete list of the molluscs is given; also a lengthy table showing molluscan associations, number of specimens examined, and types of trematode infestations found. The student and particularly the investigator will find this comprehensive study with its numerous drawings, charts, and lengthy bibliography of great value. It would seem to have merited an index.

THE MARINE DEPOSITS OF THE ARABIAN SEA. *An Investigation into Their Distribution and Biology. The John Murray Expedition 1933–34. Scientific Reports. Volume III, No. 2.*

By H. G. Stubbings. British Museum (Natural History), London. 15s. 12 x 9¼; 128 + 4 plates + 4 charts; 1939 (paper).

CRINOIDEA. *The John Murray Expedition 1933–34. Scientific Reports. Volume IV, No. 4.*

By Austin H. Clark. British Museum (Natural History), London. 2s. 12 x 9¼; 22 + 1 plate; 1937 (paper).

The first of these surveys consists of 185 samples of deposits from 131 stations. Included in the report is the distribution of the main types of marine deposits obtained from earlier reports—also a survey of the region of Zanzibar. References, maps, and illustrations of sample deposits add to the usefulness of this very excellent report.

Sixteen species of Crinoids were collected (Indian Ocean). Of this number 5 were new and one represented a new genus. The author has included in the present list all of the crinoids known in the seas from the west coast of Ceylon to the west coast of India. A bibliography of 48 titles is included and illustrations of the five new species.

THE MIGRATION OF AMERICAN BIRDS. *By Frederick C. Lincoln. Illustrated by Louis Agassiz Fuertes. Doubleday, Doran and Co., New York.* $4.00. 10 x 7½; xii + 189 + 12 plates; 1939.

The author of this book has devoted many years to the subject of bird migration. His position in the Biological Survey has made him the focus for all bird migration records in the United States. From the wealth of data now in the files of the Survey the migration of North American birds is fairly well mapped out. Although the origin of migration is a problem not yet solved, the routes, time of arrival and departure, distances covered, etc., are all well known for most of our birds. The mechanics and dangers of migration, the flyways systems, the different types of migration are some of the major topics. In the chapter on bird banding is a series of the more interesting banding operations which reveal not only the remarkable distances traversed by the birds, but also give interesting clues to their duration of life. There are several color plates and maps.

LA MÉCANIQUE DU POISSON DE RIVIÈRE. *Qualités Nautiques du Poisson; Ses Méthodes Locomotrices; Ses Capacités; Ses Limites; Résistances du Fluide; Effet de la Vitesse, de la Pente; Résistance de Seuil.*

By G. Denil. Goemaere, Imprimeur du Roi, Bruxelles. 9½ x 6¼; 395; 1938 (paper).

In this account on the mechanics of fish the writer discusses first the shape and locomotion of the fish, admirably built for their aquatic existence; second, the physical obstacles imposed by the water which the fish has to overcome; and third, the application of known physical principles and laws of water and bodies in water to the construction of fish ladders that permit their crossing over man-made barriers. There are three forces working against the fish—that of speed of the water, the slope of the flow (the presence of such a force is elaborately described) and a force which the writer calls *résistance de seuil*. An important contribution to a little known phase of fish study, of necessity rather technical.

THE BOOK OF FISHES. *Revised and Enlarged Edition, Presenting the Better Known Species of Food and Game Fishes of the Coastal and Inland Waters of the United States.*

Edited by John O. La Gorce. National Geographic Society, Washington, D. C. $3.50. 10 x 6¾; 367; 1939.

No one with a grain of sporting blood can glance through the pages of this volume without wanting to try out his flies and plugs. But the book not only holds fascination for the angler but for the biologist as well. Descriptions and life histories of the most important of the marine inhabitants of the United States are presented by some of the foremost ichthyologists of this country. They tell of the anatomy, distribution, reproduction, methods of catching, and commercial importance of these forms, besides countless other points of interest. The chapter entitled "Market Fish Have Many Names" will be a revelation to the gourmet. The book closes with an interesting article on fossil fishes. The written material is augmented by about 400 excellent drawings in color and action photographs. There is a thorough index to the volume.

INTRODUCTION TO VERTEBRATE ZOOLOGY. *By William H. Atwood. C. V. Mosby Co., St. Louis.* $3.75. 8½ x 5½; 511; 1940.

One of the most complete textbooks of the vertebrates that has come to the reviewer's attention. The term "Vertebrata" is construed in the broadest sense to include the lancelets, the ascidians, and the Enteropneusta, which since the admission of King Phoronis himself, has become quite a home for incurables.

Within the phylum a great deal of attention is given to unusual forms, such as the ostracoderms, the lungfishes, the extinct amphibians and reptiles, the tinamore and the hoatzin (many systematists will disagree with the author's opinion of the taxonomic position of these), the exotic marsupials, the Galeopithecidae, etc. The embryology as well as the adult anatomy of all these is discussed, and various

theories of derivation are detailed. This is far more than a laboratory manual; it is a useful work of reference.

EYES IN THE NIGHT.

By Tappan Gregory. Thomas Y. Crowell Co., New York. $3.50. 9 x 6½; xi + 243; 1939.

This volume includes nearly 50 night-time photographs of most elusive and beautiful wild animals—from the tiny field mouse to the mountain lion. Mr. Gregory, a Chicago lawyer, has made expeditions into Mexico and other out of the way places in quest of wild animals. He has photographed wolves in Louisiana, baby foxes in Illinois, black bear and deer in northern Michigan, as well as mice and squirrels in his own back yard.

The text describes the pictures and how they were achieved. Also there are detailed descriptions of different kinds of apparatus used. All of the photographs are interesting and excellent of their kind and many are unusually beautiful, especially those of the deer.

PRINCIPES DE ZOOLOGIE AGRICOLE. *Collection Armand Colin No. 223.*

By Paul Vayssière. Armand Colin, Paris. 15 francs (paper); 17.50 francs (cloth). 6¾ x 4¼; 224; 1940.

The great economic loss to agriculture which results from animal infestations inspired the publication of this volume. The author feels that his own country, France, is particularly backward in research in this field, and hopes that his review of the problems will direct attention toward their solution. He shows the complexity of the interrelation between plants and animals, and discusses the control of plant parasites by means of physical factors (lethal temperatures, etc.), biological factors (parasites of the destructive organism), and chemical factors. Further chapters describe the distribution and dispersion of agricultural pests and the problems encountered in dealing with nematodes and migratory insects.

NATURAL HISTORY AND METHOD OF CONTROLLING THE STARFISH (ASTERIAS FORBESI, DESOR). *U. S. Department of the Interior. Bureau of Fisheries. Bulletin No. 31.*

By Paul S. Galtsoff and Victor L. Loosanoff. Government Printing Office, Washington. 20 cents. 11 x 7½; 58 + 4 plates; 1939 (paper).

The sudden increase in the starfish population in shellfish areas has generally been regarded by oystermen as an "invasion." The erroneousness of this notion has been demonstrated by the authors of this bulletin, who have surveyed the numbers of starfishes and the changes in their distribution in Buzzards and Narragansett Bays, Long Island Sound, and lower Chesapeake Bay. The movements of starfishes are extremely slow, and quite limited in extent. Local increases in their numbers should be attributed primarily to the increased rate of propagation and survival of the local stock.

ANIMALS ARE LIKE THAT!

By Frank Buck with Carol Weld. Robert M. McBride and Co., New York. $2.50. 8½ x 5½; 240 + 15 plates; 1939.

Once again "Bring 'Em Back Alive" Frank Buck writes of his animal acquaintances both roaming and behind bars. In this book he describes his elephant friends whom he considers the most intelligent of all beasts, devoting other chapters to the amusing antics of apes and monkeys, lions and tigers, and numerous other jungle inhabitants. The work is a record of continuous activity, of conquering and living in close quarters with animals both in captivity and in their native habitat, and contains much unusual and interesting information.

THE QUADRAT METHOD OF STUDYING SMALL MAMMAL POPULATIONS. *Scientific Publications of the Cleveland Museum of Natural History. Volume V, Number 4.*

By B. P. Bole, Jr. Cleveland Museum of Natural History, Cleveland. $1.00. 9¼ x 6; 63; 1939 (paper).

In the studies of small mammal popula-

tions, especially when dealing with total numbers present, various trapping techniques have been developed. These methods are reviewed by the writer who concludes, as a result of his own experiments and studies, that the quadrat method is the best. The larger the quadrat the more accurate the results. More than one quadrat should be used, but they should not be placed too close together, nor should any one encompass different ecological areas. The results of systematic trapping of small mammals in Ohio are summarized.

BRITISH BLOOD-SUCKING FLIES.

By F. W. Edwards, H. Oldroyd, and J. Smart. British Museum (Natural History), London. 15s. 10 x 6¾; viii + 156 + 45 plates; 1939.

The blood-sucking flies of the British Isles are fully described in this beautifully illustrated volume. Each of the three authors has taken a separate sub-order (Nematocera, Brachycera and Cyclorrhapha) and has listed the species to be found within the prescribed range, their habits and peculiarities, and in some cases, described some new forms. In addition to the illustrations, there are keys and bibliographies that together make this volume a noteworthy contribution to the entomology of Great Britain.

FLEAS OF EASTERN UNITED STATES.

By Irving Fox. Iowa State College Press, Ames, Iowa. $3.00. 8¾ x 6; vii + 191; 1940.

Detailed descriptions of all the *Siphonaptera* found east of the one-hundredth meridian are given in this book. Numerous drawings show the principal identifying structures. In a brief introduction the author gives the general morphology, methods of collection and preservation, and methods by which these parasites can be controlled. In view of the medical importance of fleas and the general lack of information concerning them, the book will probably have ready acceptance.

VOICES FROM THE GRASS.

By Julie C. Kenly. Illustrated by Henry C. Kenly. D. Appleton-Century Co., New York and London. $2.00. 7⅝ x 5¼; xvii + 248; 1940.

Another book written for the young on the fascinating behavior of the insect world. Mrs. Kenly tells the story of the spider, the ant, the firefly and of many other familiar yet mysterious creatures. The book is documented and indexed and illustrated with simple black and white drawings.

THE TETRAPOD REPTILES OF CEYLON. *Volume I. Testudinates and Crocodilians. Ceylon Journal of Science. Colombo Museum Natural History Series.*

By P. E. P. Deraniyagala. The Director, Colombo Museum, Ceylon; Dulau and Co., London. Rs. 10, or in England, 15s. 9½ x 7⅛; xxxii + 412 + 24 plates; 1939.

Much careful work has gone into the preparation of this volume which discusses history of local herpetology, collecting, classification, orders of Reptilia in Ceylon, etc. The larger part of the report is concerned with the two suborders of Testudinata—Athecoidea and Thecophoroidea—and with the order Emydosauria. Many text figures and plates are included, also tables of measurements (62), a systematic index, glossary, a lengthy bibliography, and indexes of both English and scientific names as well as author's index.

THE AMPHIBIA AND REPTILIA OF OREGON.

By Kenneth Gordon. Oregon State College, Corvallis, Oregon. 50 cents. 10½ x 7½; 82; 1939.

Herein are given the description, range, habitat of the amphibia and reptiles known to occur in Oregon and a few that probably are to be found in that state. There are keys and illustrations as an aid in identification, a bibliography, as well as introductory notes on distribution, snake bites, etc.

A CONTRIBUTION TO THE HERPETOLOGY OF FLORIDA. *University of Florida Publication. Biological Science Series, Vol. III No. 1.*

By Archie F. Carr, Jr., University of Florida, Gainesville. $1.35. 10 x 7; [4] + 118; 1940 (paper).

An annotated list, with notes on life histories, abundance, and range. There is an extensive discussion of the derivation and distribution of this fauna, a key, a bibliography, but no illustrations.

BIRDS OF EASTERN NEWFOUNDLAND. *Scientific Publications of the Cleveland Museum of Natural History. Volume IV, Number 2.*

By John W. Aldrich and David C. Nutt. Cleveland Museum of Natural History, Cleveland. 50 cents. 9¼ x 6; 30; 1939 (paper).

The birds of eastern Newfoundland are listed with the description of two new subspecies, the Newfoundland black-capped chickadee and the black-backed robin. There is a bibliography and a brief introduction.

ZOOLOGICA. *Scientific Contributions of the New York Zoological Society. Volume XXIV, Part 4, Numbers 27–31.*

New York Zoological Society. Zoological Park, New York. $1.40. 10½ x 7; 119 + 5 plates; 1939 (paper).

BOTANY

AMERICAN HUSBANDRY.

Edited by Harry J. Carman. Columbia University Press, Morningside Heights, N. Y. $5.00. 8½ x 5½; lxi + 582; 1939.

A reissue of a volume that first appeared in 1775—author unknown. The soil, climate, agricultural products, and practices of English colonies in America are described in Nova Scotia, Canada, the Atlantic states, the West Indies, and the Ohio and Mississippi valleys. It is pointed out that the navigability of the Mississippi and Ohio rivers together with the fertility of the soil and its suitability for raising valuable staples make this region one of great potential wealth.

Two critical reviews of the book, the first appearing in 1776 and the second in 1918, are included. The most probable author of the volume is discussed in the review (1918) by Lyman Carrier and in a report by Harry J. Carman. The former holds the author to be Dr. John Mitchell, a botanist who lived in both England and America. The latter holds that methods of historical detection must cause us to discard Dr. Mitchell and leave the writer in the limbo of the forgotten.

THE GENERAL ASPECTS OF THE VEGETATION OF EUROPE.

By Marietta Pallis. Taylor and Francis, London. 3s. 6d. net. 9½ x 6½; [6] + 66 + 1 folding table; 1939 (paper).

The main thesis of this study, with the vegetation of Great Britain, Roumania and Greece taken as representative of the state of the vegetation in Europe generally, is that, except above the altitudinal tree-level, the natural vegetation was forest and that grassland and other forms of degraded vegetation spread by the interference of animals and man. Among the author's conclusions and surmises are:

> Schimper's forest climate necessarily antedates the dicotyledonous tree in the Upper Cretaceous. There has probably been a forest period since then—almost unbroken forest—in Europe at any rate, excluding the Ice Age of the Pleistocene, after which there was re-establishment of the forest as the dominant cosmic formation. . . .Primitive vegetation is more often simple with one dominant, but where the flora is rich there may be several. Degraded vegetation is usually complex, with no dominant, but instead a veering multitude of species. . . .Extinction may come through external causes or, it is suggested, through constitutional change—senescence—as regards both the vegetative and the sexual reproductive process.

FIELD TRIALS. *Their Lay-out and Statistical Analysis.*

By John Wishart. Imperial Bureau of Plant Breeding and Genetics, School of Agriculture, Cambridge. 2s. 6d. 10 x 8¼; 36; 1940 (paper).

The amount of any given kind of seed at the disposal of a plant breeder is frequently very limited. And, as every experimenter knows, this makes it difficult to obtain data on yield that is free from experimental error on the one hand and from seasonal or soil differences on the other. A great deal of error and expense can be avoided, however, by careful planning of experiments. Some methods of arranging field trials are suggested in this bulletin, and correct methods of working-out and interpreting the resulting data are outlined. There are sections devoted to the methods of randomized blocks and Latin-square planting, to multiple-factor experiments, to "confounding," and to experiments with large numbers of varieties.

THE TRANSVERSE REACTIONS OF PLANTS. *Outlines of a New Interpretation of the Significance of Growth Hormones for Life-Processes in Plants.*

By Georg Borgström. Einar Munksgaard, Copenhagen; C. W. K. Gleerup, Lund; Williams and Norgate, London. Dan. Kr. 7.50. 9½ x 6½; 230; 1939 (paper).

This publication outlines a hormonal interpretation of life-processes in plants. The discussion is based upon experimental work performed by the author and upon research work of others. The concept set forth is that reactions in plants can be fully explained by a transverse hormonal action. The response of the plant organism to its environment is the resultant of polar and transverse hormonal action. The polar component is, by and large, responsible for longitudinal growth. The transverse component is responsible for phototropic, geotropic, temperature, mechanical, and specific substance reactions. This hypothesis allows a new interpretation to be given to the mutual correspondence of external factors.

The text contains 58 figures, an extensive bibliography is present, and English, German, and Russian summaries are appended at the end of the report.

A MANUAL OF THE LIVERWORTS OF WEST VIRGINIA. *Reprinted from "The American Midland Naturalist," Vol. 23, 1940.*

By Nelle Ammons. The University Press, Notre Dame, Ind. (Obtainable from the Editorial Office of the American Midland Naturalist.) $1.75. 9⅛ x 6; 164; 1940.

LIVERWORTS OF SOUTHERN MICHIGAN. *Bulletin No. 17.*

By William C. Steere. Cranbrook Institute of Science, Bloomfield Hills, Mich. 50 cents (paper); $1.00 (cloth). 9 x 6; 97; 1940.

Both of these manuals are excellent; that dealing with the liverworts of West Virginia (with its lengthy bibliography) is rather for the advanced student than for the beginner. The Michigan manual will be found an excellent introduction for those wishing a guide to the commoner members of the liverwort family. Both are illustrated and contain keys, glossaries, and indexes.

LA REPRODUCTION CHEZ LES PLANTES.

By Roger Heim. Librairie Armand Colin, Paris. 15 francs (paper); 17.50 francs (cloth). 6¾ x 4½; 219; 1939.

A study of the reproductive processes of plants brings to light more facts concerning plant biology and natural history than that of any one of the other physiological processes. This fact is more fully appreciated when it is realized that the classification of plants, and particularly the higher ones, depends largely upon the morphological characteristics associated with reproduction. Upon this fundamental basis, M. Heim has developed a most interesting discussion of plant reproduction. The age-old principle of alternation of generations for each phylum of plants is discussed in the light of evolution, morphology, physiology, and cytology. The text is well illustrated and documented, and the factual material is brilliantly augmented by the abundance of pertinent examples drawn from the author's own experience.

BACTERIOLOGY. *Clio Medica.*

By William W. Ford. Paul B. Hoeber, Inc., Medical Book Department of Harper

and Bros., New York and London. $2.50. 6½ x 4¼; xi + 207; 1939.

Dr. Ford has written a chronological story of the growth of man's knowledge about bacteria. He presents not just the high lights alone—the classical experiments—but also the observations and deductions which are the foundations of the great discoveries. The picture of the changing relationships between bacteriology and other scientific fields, a fine study of give and take, is especially interesting not alone because Pasteur was first a chemist, but even more because of the important part played today by bacteriology in, for example, preventive medicine, therapeutics, the preservation of foods, and agriculture.

ADAPTATION AND ORIGIN IN THE PLANT WORLD. *I. Factors and Functions in Coastal Dunes.*

By Emmett V. Martin and Frederic E. Clements. Carnegie Institution of Washington, Washington, D. C. 50 cents. 10 x 6¾; viii + 107 + 5 plates; 1939 (paper).

The prevailing assumption that xerophytism in plants is most marked by leaf transformation is attacked in this study. Quantitative measurements were made on plants growing in several dune habitats and in a control habitat. It was found that plants grown in fertilized soil have, on the average, thicker leaves. The number of stomata varied so greatly among the several species that it was impossible to formulate a general rule. The same was true as regards transpiration. Extensive tables of the values for habitats used in the course of this research are given; 57 titles are included in the bibliography, and 32 illustrations and 5 plates are appended.

ESPERIENZE SULLA PRODUZIONE DEGLI OLII PER VIA MICROBIOLOGICA *Nel Quadro Autarchico dell' Approvvigionamento dei Grassi in Italia. I. Il Lavoro Agricolo e l' Autarchia.*

By P. G. Garoglio and Raffaele Ciferri. Confederazione Fascista dei Lavoratori dell' Agricoltura, Roma. 3 Lire. 9⅝ x 6½; 35; 1940 (paper).

In this paper the authors give a summary account of a series of experiments designed to compare the fat content of several species and genera of fungi. Six species of *Mucor*, 6 species of *Penicillium* and 5 species of other assorted genera were cultivated under comparable conditions and the quantity and physicochemical properties of the fats extracted were assayed. The authors conclude that the commercial production of fats from microorganisms is feasible, and recommend its adoption as part of the present Italian efforts towards economic autarchy. A short bibliography is appended.

GROWING PLANTS IN NUTRIENT SOLUTIONS: *or Scientifically Controlled Growth.*

By Wayne I. Turner and Victor M. Henry. John Wiley and Sons, New York; Chapman and Hall, London. $3.00. 9 x 6; xiii + 154 + 3 plates; 1939.

In order that the lay reader might better understand soilless plant culture, the authors have included in this book the fundamentals of plant physiology and of the necessary chemistry. Although a large part of the volume is devoted to nutrient culture on a commercial scale, the window-box farmer is not neglected. Detailed instructions are given for the construction of benches and tanks, and for the mixing and testing of formulae. The authors advocate replenishing used solutions rather than discarding them, and they include a chapter on the recognition of plant deficiencies. The written material is clarified by numerous photographs and diagrams.

EXPERIMENTELLE CYTOLOGIE.

By Hans H. Pfeiffer. Chronica Botanica Co., Leiden; G. E. Stechert and Co., New York. 7 guilders or about $3.70. 9½ x 6¼; xii + 243; 1940 (paper).

This work is confined entirely to the plant cell, its physical properties, morphology, aging and necrosis, and experiments with vital stains. Emphasis has been placed on the more recent studies. The author plans to treat the chemical, genetic and cytophysical aspects in later volumes.

The present work is Volume 4 of the *New Series of Plant Science Books*, edited by Frans Verdoorn.

MORPHOLOGY

FUNCTIONAL HUMAN ANATOMY.
By Cleveland P. Hickman. Illustrated by Frances M. Hickman. Prentice-Hall, Inc., New York. $3.75. 9 x 6; xxxv + 501; 1940.

It would seem that there is just cause in the academic world for welcoming this excellent text. That there is need for such a volume requires no emphasis. Its aim is to present to students of elementary human anatomy a functional interpretation of bodily structures. No preliminary training in the biological sciences on the part of the student has been assumed. The material has been divided into two parts. The first emphasizes the descriptive and applied aspects of the subject; the second deals with the practical study which the student is called upon to do for himself. Since the student of elementary anatomy is not ready to dissect the actual structures of the human body, the practical study has centered around a mammal, such as the cat.

The illustrations have been made with considerable care and forethought. Much information of anatomical value will be found in the appendices, and the work concludes with a list of practical review questions, a glossary of technical terms, a list of references, and a carefully prepared and complete index.

A BRIEF ANATOMY OF THE TURTLE.
By Glenn A. Noble and Elmer R. Noble. Stanford University Press, Stanford University, Calif.; Oxford University Press, London. $1.00. 8½ x 5½; viii + 48 + 21 plates; 1940 (paper).

The turtle, as a representative of the class Reptilia, has long been used in zoology and comparative morphology courses. This book, based on a study of the California mud turtle, *Clemmys marmorata*, is intended for use as a brief but adequate laboratory guide in such courses. The first part of the book is devoted to a discussion of the organ systems; the latter part, to plates illustrating these systems. Most stress is laid on the muscular, circulatory, nervous, and skeletal systems; the digestive, respiratory, urogenital, and endocrine systems and the embryology of the turtle are treated in less detail. A bibliography is included.

PHYSIOLOGY AND PATHOLOGY

A HISTORY OF TROPICAL MEDICINE: *Based on the Fitzpatrick Lectures Delivered before the Royal College of Physicians of London 1937–38. In Two Volumes.*
By H. Harold Scott. Williams and Wilkins Co., Baltimore. $12.50 per set. 9 x 5¾; xix + ix + 1165 + 13 plates; 1939.

This history of the so-called tropical diseases fittingly begins with the progress of hygiene in the navy, mercantile marine, and army (particularly the English), the personnel of which were among the first Europeans to come into contact with these diseases, and sometimes to cause their introduction into the home country. Instances are cited to show how expeditions, campaigns, and battles were lost due to the incapacity or death of troops by malaria, yellow fever, dysentery, etc., together with methods carried out to prevent these losses to the time of the Italo-Abyssinian war in which, among 500,000 Italian troops only 1241 cases of primary malaria and only 23 deaths from this disease were reported.

Then the author treats the diseases—malaria, blackwater fever, yellow fever, trypanosomiasis, leishmaniasis, leprosy, cholera, plague, undulant and relapsing fevers, melioidosis, dengue, amoebic dysentery and hepatitis, ankylostomiasis, and the avitamose diseases—separately, with regard to early history, incidence and spread (including areas other than tropic), records of outbreaks, history of research on the causative bacillus and mode of transmission, measures for control and cure. Concluding chapters tell the story of the construction of the Suez and Panama canals, the rôle of the slave trade in the

spread of disease, and the lives of a few men with claims of renown in the field of tropical medicine and sanitation.

A philosophic trend, with particular emphasis on social and economic implications, runs throughout the book. Much of it, particularly references to personalities connected with research on causative agents and methods of control, reads like a romance—the triumph over yellow fever and the building of the Panama canal are the classical examples.

This is a solid, scholarly work, but it is regrettable that the bibliography (only 8½ pages) has not been extended. Author and subject indices have been supplied.

THE MAMMOGENIC HORMONES OF THE ANTERIOR PITUITARY. *I. The Duct Growth Factor. University of Missouri. Agricultural Experiment Station. Research Bulletin 310.*

By A. A. Lewis and C. W. Turner. University of Missouri, Columbia. Free. 9 x 6; 72; 1939 (paper).

There appear to be two factors in the mammogenetic hormone secreted by the anterior pituitary, one of which stimulates the growth of the duct system and the other the lobule-alveolar system of the mammary glands. It is with the former of these that this study is concerned. Among the findings obtained from 545 cattle pituitaries assayed for their content of the duct growth factor of mammogen were:

> The mammogen content of AP from pregnant dairy and beef cows was found to be low in early and late pregnancy, rising to a peak at about 150 days. . . .Non-pregnant cows were found to have an appreciable amount of mammogen in the pituitary. The content was highest in lactating dairy cows. . . . Two beef heifer groups, with corpora lutea, had 40 to 60 per cent more mammogenic hormone per AP than did pregnant beef cows at the 150 day peak. A similar group of beef heifers with only follicles in the ovaries had a low content of mammogen in the AP. . . .Dairy steers had 83 per cent as much mammogen per AP lobe as did dry non-pregnant dairy cows, with follicles. Beef steers weighing 500 to 700 and over 700 pounds had a low content of mammogen in the AP. . . .Fetal pituitaries contained an appreciable amount of hormone.

Data are also reported for smaller numbers of rabbits, mice and ground squirrels. A bibliography is appended.

DIE BIOLOGISCHE REAKTION. *Eine funktionelle Analyse und Synthese biometrischer Werte zur Zahlenmässigen Erfassung von: Allergie, allgemeiner Resistenz, spezifischer Resistenz, Krankheitsintensität, Extensität aktiver Herde, Immunität.*

By O. H. Bucher-Trümpler and C. C. Hofflin-Karwatzki. Verlag Hans Huber, Bern. 42.80 francs; R.M. 25.70. 10¼ x 7¼; 267; 1939.

This treatise grounds itself upon a sort of quantified pathometric index for tuberculosis, derived fundamentally from differential leucocyte counts with and without stimulation by tuberculosis. The scheme for computing and combining the variables involved is a complicated one, that is explained with something short of easy and complete clarity. The bulk of the book is devoted to detailed discussions of individual cases of tuberculosis, with colored graphs of bewildering complexity showing the course of the variables and derivative biometric data from them accompanying the text account of each case. The interest of the book is for the clinical worker in tuberculosis. It obviously represents an enormous amount of careful, serious and sincere work. But in our opinion it will be necessary, before the author's ideas can be intelligently applied or evaluated by others, for someone competent in mathematics, statistics, and clinical medicine to take time off and present a simple, clear, and straightforward account of just exactly what the technique is, and how it is to be used. The present treatise, in short, is obscure. It is beautifully printed.

ON OXIDATION, FERMENTATION, VITAMINS, HEALTH AND DISEASE. *The Abraham Flexner Lectures, Series Number Six.*

By Albert V. Szent-Györgyi. Williams and Wilkins Co., Baltimore. $2.00. 8 x 5¼; xi + 109; 1939.

Five lectures delivered by the author in 1939 at Vanderbilt University are embodied in this volume. The first four summarize his well-known biochemical investigations on oxidation and cellular and tissue respiration. Taking as his starting point the elementary formula for

the oxidation of carbohydrates the author almost painlessly introduces the reader to what is probably the most complex aspect of biochemistry. In clear and concise terms he first describes the fundamental researches of Warburg and of Wieland and then outlines his own studies which, among other things, led to the discovery of ascorbic acid. The last lecture contains an interesting discussion of vitamins and their bearing on health. Two somewhat novel views on the subject are advanced. The first is that the lack of a vitamin forming mechanism in man is another indication of his descent from a creature that lived in a region rich with vegetation. The second refers to the human requirements of vitamins. The belief is expressed that the administration of larger than the usual therapeutic amounts of vitamins would serve to increase bodily vigor and promote health; therefore, a plea is made for more investigations on the optimum dosages of vitamins for man.

FOOD CONTROL: *Its Public-Health Aspects. A Manual for Regulatory Officers, Food Technologists, and Students of the Food Industry.*

By James H. Shrader. John Wiley and Sons, New York; Chapman and Hall, London. $4.00. 9 x 5¾; ix + 513; 1939.

The large consumption of processed, preserved, and stored food by urban populations has made their control an important public health measure. The writer points out that it is not only the duty of public health administrations to see that untainted food reaches the consumer but that these should also be within certain nutritional limits. The book is primarily a practical manual of food inspection and food laws enforcement. It should be exceedingly valuable to public health workers, food inspectors, and food industrialists. The subject matter presented will aid in conserving funds by showing the most practical methods of control for given expenditures. Two appendices dealing with the equivalence of vitamin units and a digest of the new federal statutes concerning foods, drugs, and cosmetics are present. The book is well documented and indexed.

PICTURE OF HEALTH.

By James Clarke. Illustrated by Guy Rowe. The Macmillan Co., New York. 60 cents. 7½ x 5; 125; 1940.

It is strange but true that most discussions of health deal with the subject from a negative aspect; that is they usually deal with the cause, cure, and economic importance of *bad* health. In the present volume, however, the author has developed his discussion around the positive aspects of health—his thesis being that health is the culmination of all normal physiological processes and activities.

The volume is intended for popular consumption. The discussions of the digestive, circulatory, respiratory, excretory, and nervous systems together with their activities and functions are quite frank, yet entirely devoid of the unpleasantness which many lay readers associate with a study of their "insides."

The simplicity of the terminologies, the pertinence of the examples and analogies, the clarity of the illustrations, as well as the list of books for further reading tend to make the volume a noteworthy contribution in the field of health as related to every-day living.

STUDIES IN THE DEVELOPMENT OF YOUNG CHILDREN.

By Nancy Bayley. University of California Press, Berkeley. 35 cents. 8½ x 5½; vii + 45; 1940 (paper).

In the introduction the author states that a "study of growing children must be as continuous as growth itself." It was with this idea in mind that the ten-year studies on the mental and physical development of 61 Berkeley infants (30 girls and 31 boys), born in the same year 1928–29, were carried out. All the children selected were born in hospitals; all were white, and nearly all, of North European or early American stock; also, only those infants whose parents expected to make

Berkeley their homes for many years to come were included in the study. In spite of this latter fact, the number of children diminished until at the end of the ten-year period there were 48.

The subjects studied include home and family factors, early illnesses, growth in size, trend of bone development, growth in intelligence, development of personality, and such factors as would have retarding or favoring influences on development. The results as they were obtained from month to month and year to year are briefly compiled; graphs and photographic plates are included.

FOOD AND LIFE. *Yearbook of Agriculture 1939.*

U. S. Department of Agriculture. U. S. Government Printing Office, Washington. $1.50. 9 x 5¾; xv + 1165; 1939.

Readers so literal as to expect these yearbooks to be annual summaries of governmental statistics will be pleasantly surprised to learn that they deal with different topics from year to year, and in a remarkably attractive way. The yearbooks for 1936 and 1937 summarized what is known about the improvement of crops and livestock through breeding; the one for 1938 devoted similar efforts toward illuminating the subject of "soils and men." The latest one, an encyclopedic collection of 58 essays, seeks to be as informative as possible about man's present knowledge of nutrition. One-third of the book discusses the nutrition of human beings; two-thirds of it, dealing with the nutrition of animals, contains much information of fundamental value with regard to human nutrition. A 94-page summary serves as an introduction.

VIRUS AND RICKETTSIAL DISEASES: *With Especial Consideration of Their Public Health Significance. A Symposium Held at The Harvard School of Public Health, June 12–June 17, 1939.*

Harvard University Press, Cambridge; Oxford University Press, London. $6.50. 9¼ x 6; xi + 907; 1940.

Students of infectious diseases will welcome this summary of the work so far done in the field of virus and rickettsial diseases. Our knowledge of these disease agents has increased so rapidly and on so many fronts that it is now impossible for any one person to be completely familiar with much more than his own sector. These 34 papers by authorities, most of them writing from personal experience, were given in a symposium at Harvard in the summer of 1939. It was thought best to include reviews of the literature of those phases of the study not under active investigation at the school, in order to present an integrated survey of this interesting field. Each paper, nevertheless, is complete in itself, making the volume a useful reference work as well.

RECENT ADVANCES IN MEDICAL SCIENCE. *A Study of their Social and Economic Implications. The Rede Lecture Delivered Before the University of Cambridge on 28 April 1939.*

By Sir Edward Mellanby. The Macmillan Co., New York; The University Press, Cambridge. 75 cents. 7¼ x 4¾; 62; 1939.

This lecture gives us a very clear picture of the general improvement in health, made possible by increased medical knowledge. He calls our attention to the discovery of numerous synthetic drugs successfully used in the cure of disease and control of symptoms, and to continually increased understanding of the causes of disease. He shows that life expectancy is reaching higher figures, while infant mortality is sinking to lower ones and that between the two the average age is increasing, thus creating new problems in social and economic fields. The book is interesting and instructive, and bestirs thought on the problems presented.

THE MEDICAL CAREER *and Other Papers.*

By Harvey Cushing. Little, Brown and Co., Boston. $2.50. 8 x 5¼; vii + 302; 1940.

In this book, published posthumously, is presented a collection of 16 essays by Harvey Cushing. The first seven are

addresses delivered at various medical occasions and deal with topics of medical interest, contemporaneous and historical. Throughout them runs the humanistic trend which so strongly characterizes Dr. Cushing's other writings. The last nine essays are brief biographical sketches of men whose contributions to medical thought and practice have been outstanding: namely, Welch, Beaumont, Halsted, James Ford Rhodes, George Strong Derby, Perry Williams Harvey, Haller, Councilman, and the Mayos. The essays are characterized by warmth and charm. We particularly recommend the volume to medical students. The publishers announce that coincident with its publication they are bringing out, in uniform size, a new edition of Dr. Cushing's *Consecratio Medici*.

FETAL AND NEONATAL DEATH. *A Survey of the Incidence, Etiology, and Anatomic Manifestations of the Conditions Producing Death of the Fetus in Utero and the Infant in the Early Days of Life.*

By Edith L. Potter and Fred L. Adair. University of Chicago Press, Chicago. $1.50. 7⅝ x 5¼; xv + 207; 1940.

Since the neonatal death rate has remained practically stationary in comparison to the great decline in post-neonatal mortality, there has been great interest aroused in the causation and prevention of these deaths. Unfortunately the true cause of death is in many cases erroneously determined unless an autopsy is performed. As an aid to arrive at an accurate cause of death, this book first describes the normal fetus and infant, then the methods of a post-mortem examination. There then follows a discussion on the major causes of death—attributable mostly to prematurity, birth trauma, anoxemia, infection, and unfavorable exposure immediately after birth. A chapter on the special pathology of the new born concludes the volume.

NUTRITIONAL STUDIES IN SHANGHAI. *A report upon the nutritional status of certain Shanghai Groups 1937–39, dietary surveys and a study of the value of various food supplements. Chinese Medical Association. Special Report Series No. 12.*

By H. C. Hou, P. G. Mar, T. G. Ni and B. E. Read. Chinese Medical Association, Bookselling Dept., Shanghai. $1.00. 9¾ x 6½; [4] + 92; 1939 (paper).

After the outbreak of the Sino-Japanese hostilities in Shanghai (August, 1937) the number of refugees rapidly grew until upwards of 200,000 were gathered in empty houses and matshed camps. Mostly they were fed by charity. This interesting report is concerned with diet and nutritional deficiencies among refugees; nutritional supplements for refugee children; their height and weight measurements; height-weight measurements of refugee children given soybean milk, etc. The last three chapters are: Physical measurements of Cantonese school boys in Shanghai; Height-weight measurements of Shanghai school children; A nutritional survey of three groups of Shanghai families. Numerous tables and graphs are included in the text and each chapter is summarized and concludes with a bibliography.

RECENT ADVANCES IN NEUROLOGY. *Fourth Edition.*

By W. Russell Brain. The Blakiston Co., Philadelphia. $5.00. 7⅞ x 5¼; ix + 364; 1940.

The fact that this is the fourth edition of a book which made its first appearance only eleven years ago attests to the high regard in which Dr. Brain's work is held. In the present edition the subject matter has been largely rewritten, and seven new chapters have been incorporated. Subjects which are now discussed for the first time or in which important advances have been made include: the pathogenesis and treatment of headache, the functions of the frontal lobe, vitamin deficiencies in relation to nervous disorders, diseases due to neurotropic viruses, muscular disorders associated with thyroid disease, and the treatment of meningitis with sulphanilamide. The illustrations, the excellent and numerous references, and the complete index add to the value of this book.

AN INTRODUCTION TO EXPERIMENTAL HUMAN PHYSIOLOGY

By W. W. Tuttle and G. Clinton Knowlton. C. V. Mosby Co., St. Louis. $1.50. 10½ x 7¾; 138; 1939 (paper).

The paramount idea in presenting the material included in this laboratory guide is to enable the beginner in physiology to familiarize himself with the techniques involved in demonstrating the fundamental phenomena of this subject. Insofar as possible experimentation is placed in the hands of the student; and, where practicable, the students themselves are used as subjects for the experiments. A total of 44 experiments are presented with space provided for the answers to the questions at the end of each experiment. The appendix furnishes many important and helpful details of procedure. The manual has references throughout to Zoethout's *Textbook of Physiology*.

MEDICAL EDUCATION IN THE UNITED STATES 1934–1939. *Prepared for the Council on Medical Education and Hospitals of the American Medical Association.*

By Herman G. Weiskotten, Alphonse M. Schwitalla, William D. Cutter and Hamilton H. Anderson. American Medical Association, Chicago. $1.00. 10⅝ x 7⅝; [12] + 259 + 4 charts; 1940 (paper).

This book contains the report of a survey of the medical schools of the United States and Canada, made under the guidance of the American Medical Association through its Council on Medical Education and Hospitals. The survey has been most intensive, and the result is a particularly complete analysis of the administrative organization, educational requirements, hospital connections and clinical facilities, student responsibilities, and general qualifications of the schools. A study of distinct value to men and women desiring to enter the medical profession, in determining which school may satisfy their individual preference.

JEWISH CONTRIBUTIONS TO MEDICINE IN AMERICA: *From Colonial Times to the Present. Second Edition, Revised and Enlarged.*

By Solomon R. Kagan. Preface by James J. Walsh. Boston Medical Publishing Co., Boston. $3.50. 8⅝ x 6; xxxi + 794; 1939.

This lengthy survey of the scientific activities of outstanding American-Jewish physicians from colonial times to the present gives an excellent picture of the extent to which Jewish contributions have helped to advance medical science. It is arranged as a series of biographical sketches and historical facts in chronological order. The appendices include an outline of Jewish medical chronology and a list of Jewish medical institutions. The latter part of the book forms a supplement to the first and main body. Photographs and bibliography and separate indices for each of the two divisions are included in the volume.

CANCER MORTALITY IN THE UNITED STATES. *I. Trend of Recorded Cancer Mortality in the Death Registration States of 1900, from 1900 to 1935. U. S. Public Health Service. Public Health Bulletin No. 248. II. Recorded Cancer Mortality in Geographic Sections of the Death Registration States of 1920, from 1920 to 1935. U. S. Public Health Service. Public Health Bulletin No. 252.*

By Mary Gover. Government Printing Office, Washington. 10 cents each. 9¼ x 5¾; I, vi + 58; 1939 (paper). II, vi + 74; 1940 (paper).

A valuable addition to cancer records. Both studies add considerable statistical knowledge to that already accumulated on the occurrence of cancer in the white and colored races in the United States. The data collected must increase the speculative assumptions as to the causes of the disease, and intensify research as to the possible similarity of reasons for susceptibility in individuals.

TRAITÉ DE L'IMMUNITÉ DANS LES MALADIES INFECTIEUSES. *Deuxième Édition.*

By Jules Bordet. Masson et Cie, Paris. $3.30. 10 x 6¾; v + 879; 1939 (paper).

This long overdue second edition of one of the great classics of immunology adds 160

pages to the text. The bibliographic documentation has been improved in respect of the method of citation, but still leaves something to be desired by American standards. There is no index, a deplorable omission in an important reference work such as this. But even with these defects the volume will be welcomed by all immunologists as setting forth the mature views of its distinguished author.

ELEMENTS OF HUMAN PHYSIOLOGY. *By Miriam Scott Lucas. Lea and Febiger, Philadelphia.* $4.50. 9¼ x 5¾; 400; 1940.

The present volume represents an attempt to provide a suitable presentation of human physiology for pre-professional courses which do not require the detailed discussions found in medical texts and is written from the point of view of the student and teacher of physiology—not from the viewpoint of a specialist. The discussion is presented in four parts: movement and support, integration in the body, metabolism and water balance, and reproduction and endocrine function. The illustrations are well-chosen and the index is very complete. There is no bibliography.

PROBLÈMES ACTUELS DE BIOLOGIE GÉNÉRALE ET DE PATHOLOGIE EXPÉRIMENTALE. *By Henry Bénard. Masson et Cie, Paris.* $1.05. 9¾ x 6½; 176; 1939 (paper).

This book contains six papers containing brief historical surveys and summaries on the present state of knowledge of several topics of physiological and pathological significance, namely: cellular respiration, cyanhydric intoxication, experimental pancreatic diabetes, mode of action of insulin, glucose and its deterioration, and experimental rachitis and vitamin D. Written in a clear and fluent style, in spite of the amount of material crammed into relatively small spaces, the book will be of interest to biologists as well as medical men. It lacks bibliographies.

THE PERCEPTION OF LIGHT. *An Analysis of Visual Phenomena in Relation to Technical Problems of Vision and Illumination. By W. D. Wright. Chemical Publishing Co., New York.* $2.50. 7⅛ x 4¾; [6] + 100; 1939.

This analysis of visual phenomena in relation to technical problems of vision and illumination does not pretend to exhaustiveness, but is more in the nature of an essay. The book begins with a general account of visual phenomena and then discusses vision at low and high intensities and visual sensations. There is an especially timely and helpful chapter on glare, including an illuminating discussion of the headlight problem. The concluding chapter presents the results of some recent researches in the field of light perception. There is a list of references and an index.

CARBOHYDRATE METABOLISM. *Four papers presented in a Symposium held at the meeting of the American Physiological Society at Toronto, Canada, April 29, 1939. Reprinted from Endocrinology, Vol. 26, February 1940. Association for the Study of Internal Secretions, Boston.* $1.00. 10¼ x 6¾; 285-351; 1940 (paper).

This little booklet embodies four papers presented in a symposium held at the April, 1939, meeting of the American Physiological Society, at Toronto, Canada. They are concerned with glycogen breakdown and synthesis in animal tissues, and with the relationships between the liver, the adrenal cortex, and the pituitary gland and carbohydrate metabolism. Excellent bibliographies are appended to each paper presented.

BIOCHEMISTRY

HAIR-DYES AND HAIR-DYEING CHEMISTRY AND TECHNIQUE. *By H. Stanley Redgrove and the late Gilbert A. Foan. A New Edition Completely Revised by H. Stanley Redgrove and J. Bari-Woollss. Chemical Publishing Co., New York.* $5.00. 8½ x 5½; xiv + 205 + 10 plates; 1939.

This book, first published in 1929 under

the title *Blonde or Brunette*, is a comprehensive and detailed account of hair dying and its various phases. The title has been changed from the original as the authors found "that many folk were misled by the original title in mistaking the book for a novel dealing with the claims of two rival beauties." The first part of the book is a general discussion of the structure and pigments of hair; Part II discusses dyes and bleaches specifically; Part III the art of hair dying; and Part IV goes into the causes of grey hair and supplies generous hints to those who wish to avoid premature greyness. These include not to worry "even about grey hair," and to "choose your hairdresser with care, and if he hasn't read this book, give him a copy." A bibliography has been included, but an index is lacking.

FRUIT PECTINS: *Their Chemical Behaviour and Jellying Properties. Food Investigation, Special Report No. 48.*

By C. L. Hinton. Chemical Publishing Co., New York. $1.75. 8½ x 5½; vii + 96; 1940.

This report is based on work carried out during a period of several years by members of the staff of the British Association of Research for the Cocoa, Chocolate, Sugar Confectionery and Jam Trades, and presents a study of the variations in the chemical properties of pectins, as extracted from fruits, as a basis for an eventual explanation of their jelly-forming behavior. The free acidity, the pH of the solution, the proportion of alkaline ash constituents, the methoxyl content, and the reducing power towards alkaline iodine all were found to vary widely. In view of the variations found in the properties of the pectin specimens, it is claimed that "pectin" must be regarded as a generic term covering a wide range of minor variations of molecular composition. The book contains a list of references, but no index.

BIOLOGICAL PRODUCTS.

By Louis Gershenfeld. Romaine Pierson Publishers, New York. $4.00. 9½ x 6½; ix + 244; 1939.

Persons engaged in public health, medicine, and the biological sciences will find this book a convenient source of information. The uses, dosages, preparations, and standardizations of antitoxins, serums, vaccines, immunizing toxins, toxoids, bacteriophage, allergens, etc., are adequately presented. The biological principles of handling, shipping, and storing of the products both finished and during the course of preparation are treated throughout. Federal statutes concerning both preparation and sale are also given. The lack of material upon hormonal products will be missed by many.

Extensive bibliographical references are incorporated in the body of the text. A fine index is appended. The illustrations, although interesting, add little to the subject matter covered.

MINERAL METABOLISM. *American Chemical Society Monograph Series.*

By Alfred T. Shohl. Reinhold Publishing Corp., New York. $5.00. 9 x 6; x + 384; 1939.

To describe the rôles of various minerals in the structure and function of the human body is the aim of this monograph, which was sponsored by the American Chemical Society. The field as a whole is in a phase of such rapid expansion that a simplified account rather than an exhaustive one, and an interpretation from the point of view of his own special interest, is all that the author has hoped to accomplish. He discusses the mineral composition of the body, of secretions, excretions, and internal secretions. The book is in excellent balance, and it is exceptionally informative.

REPORTS OF THE BIOCHEMICAL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE. *Vol. V, 1938–1939.*

Franklin Institute, Philadelphia. 9¾ x 7; collection of reprints.

A further collection of reprints (cf. Q.R.B., Vol. 13, p. 374) on various phases of biochemistry, histo-chemistry and physico-chemistry, with particular relation to the study of disease and medicinals. Included

also are two statistical papers, one on cancer and the other on lead poisoning, by F. L. Hoffman.

SEX

SEX AND LIFE. *Forty Years of Biological and Medical Experiments.*

By Eugen Steinach. The scientific values adapted to the lay reader by Josef Loebel. The Viking Press, New York. $3.75. 9¼ x 6⅛; x + 252 + 53 plates; 1940.

Steinach's account of the development of his ideas and investigations on the physiology of sex has been written for the layman and, according to the publisher's blurb, for "men and women, particularly those in the middle and late years, who will learn from this the startling possibilities of adding years of mental and physical vigor to life." As is to be expected, therefore, this volume is mainly concerned with the rejuvenation or reactivation operations and views associated with the author's name. Aided by beautiful illustrations, a vivid and colorful story is told of the author's well-known researches on castration and gonad implantation that finally led to the vasoligation experiments. The results obtained on man by this method are duly amplified and the first and other alleged successful operations are described in detail. The author indirectly admits that there are a number of competent investigators who question his results and theories but he seems to be more bewildered than angered by such skepticism. Unfortunately for his scientific reputation, the tone and objectives of this book will not serve to diminish this skepticism.

STERILITY AND IMPAIRED FERTILITY. *Pathogenesis, Diagnosis and Treatment.*

By Cedric Lane-Roberts, Albert Sharman, Kenneth Walker, and B. P. Wiesner. Foreword by Rt. Hon. Lord Horder. Paul B. Hoeber, Inc., Medical Book Dept. of Harper and Bros., New York. $5.50. 8½ x 5½; xx + 419; 1939.

The four co-authors of this volume have brought together the present-day knowledge of sterility, its pathogenesis, diagnosis, and treatment. A glance at the bibliography reveals that much of the literature is very recent, with the result that while great progress has been made, there are still many facts to be proven. It is to the credit of the writers that their approach to the problem is very sound and that they exercise due caution in their conclusions and recommendations.

A wealth of material is presented on both male and female sterility and impaired fertility. The constitution of normal and abnormal semen, examination and interpretation of endometrial and vaginal smears, faulty coital techniques, psychological, hormonal, and surgical treatments and therapeutics are only some of the pertinent topics ably discussed and illustrated.

SEXUAL PATHOLOGY. *A Study of Derangements of the Sexual Instinct. New Revised Edition.*

By Magnus Hirschfeld. Authorized translation by Jerome Gibbs. Emerson Books, Inc., New York. $2.95. 9 x 6; 368; 1940.

This is a new edition, stated to have been revised, of the English translation of a well-known work. It consists, in the main, of a running discussion of cases from the late author's practice as a sexologist. Hirschfeld was a pioneer in the movement for sexual reform, along with Forel and Havelock Ellis. The sort of material embodied in this book was foundational stuff for their crusade. But now it seems dated and a little boring.

BIOMETRY

A BIBLIOGRAPHY OF THE STATISTICAL AND OTHER WRITINGS OF KARL PEARSON.

Compiled by G. M. Morant, with the Assistance of B. L. Welch. Biometrika Office, University College, London. 6s. net. 10¾ x 7½; viii + 119; 1939.

In this volume the authors have carefully assembled in chronological order the list of the writings of Karl Pearson, annotated each title, and have also added a subject

index. The 648 titles have been classified into five sections. The first and most important includes 406 titles and concerns the writings on the theory of statistics and its applications to biological, social and other problems. The following four sections include the list of papers and books on pure and applied mathematics and on literary, historical and academic subjects, and the list of prefaces, notes, and reviews which have appeared in scientific journals. A sixth section contains information about the places of publication of the syllabuses of the various series of lectures given by Pearson. Biometricians and human biologists, in general, will quickly realize the great usefulness of this volume. Those who are too young to have followed as contemporaries the publications of Pearson will undoubtedly obtain from a perusal of this book a clearer idea of the broad scope of his intellectual powers and certainly a stimulus to study at first hand his contributions. The authors are to be congratulated for the evident thoroughness with which they have accomplished their task.

THÉORIE ANALYTIQUE DES ASSOCIATIONS BIOLOGIQUES. *Deuxième Partie. Analyse démographique avec application particulière à l'espèce humaine. Actualités Scientifiques et Industrielles 780. Exposés de Biométrie et de Statistique Biologique XII.*

By Alfred J. Lotka. Hermann and Cie, Paris. 45 francs. 10 x 6½; 149; 1939 (paper).

Lotka summarizes in this monograph some of the more salient features of the contributions made by him and others towards the development of what may be called mathematical demography. He presents the formulae for the analytical description of human population growth, on the basis of several assumptions, and of the principal elements related to growth such as natality, mortality and age composition. Other special aspects of demography treated in this book concern natality in successive generations, size of family and extinction of lines. Although all of these topics have been more adequately discussed in the author's previous English publications, the student of the subject will appreciate the advantage of having the formulae brought together. There is a bibliography which, as the author admits, is rather incomplete.

ADVANCES AND APPLICATIONS OF MATHEMATICAL BIOLOGY.

By Nicolas Rashevsky. University of Chicago Press, Chicago. $2.00. 7¼ x 5; xiii + 214; 1940.

Rashevsky's recent book *Mathematical Biophysics* (reviewed Q.R.B. Vol. 14, p. 106) contributed to the development of a relatively new field of science. The present extends further the application of the "approximation" method.

The approximation method attempts to take into account the size as well as the shape of the cell, the coefficient of diffusion for the substance inside the cell, the permeability of the cell membrane, and the coefficient of diffusion of the external medium in arriving at an average concentration of substance inside the cell. The average value will be found somewhere between the periphery and the center of the cell, and is expressed independently of the local structure variations which may be taking place, i.e., the movement of the centrosomes, the activity of the chromatin material, the appearance of the spindle fibers, etc. It is on this average value for the concentration of cell substance that Rashevsky bases his discussions of diffusion phenomena, cell respiration, cell division, cellular growth, cellular forms and movements, and protoplasmic streaming.

THE VARIATE DIFFERENCE METHOD.

By Gerhard Tintner. Principia Press, Bloomington, Ind. $2.50. 9¾ x 6½; xiii + 175; 1940.

Through the studies of Yule especially, statisticians have long been made aware of the difficulties which surround an analysis of time series. Yule was also one of the first to investigate the problem with some degree of thoroughness and, following Student and others, to develop the variate difference method. This method

has also been employed and further developed by the economists, among whom one may mention particularly Anderson and Zaycoff. On the basis of their researches the author studies and discusses in this book the analysis of variance and covariance of the random element of a time series. The analytical procedure outlined consists of an application of the product-moment correlation method and that of Fisher's variance theory to conditions arising from the sequences of differences between the successive terms of a time series. To facilitate the computations, which by this procedure involve very large numbers, the author has prepared useful tables which are included in the text.

AN INTRODUCTION TO MODERN STATISTICAL METHODS.

By Paul R. Rider. John Wiley and Sons, New York; Chapman and Hall, London. $2.75. 8½ x 5½; ix + 220; 1939.

Enormous and rapid advances have been made in the field of statistics, the greatest progress having been made in the theory of small samples. Most of this theory, according to Rider, has been developed and unified by R. A. Fisher, whose methods are therefore of value to all investigators who are obliged to deal with comparatively few observations. Rider's book expounds the most widely used of these methods, illustrating their application by comparatively simple numerical examples, so that the underlying principles are not lost to sight in a maze of arithmetical computations. The language of the calculus as a medium through which these methods may be communicated has not been avoided. In the earlier chapters of the book the fundamental concepts of statistics are developed; the later chapters are principally concerned with Fisher's methods; and some of Fisher's tables are reprinted as an appendix.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 2, Number 3, September, 1940.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: A generalization of Cunningham's extension of Stoke's law for a force on a sphere, by Gale Young; Physicomathematical aspects of some problems of organic form, by N. Rashevsky; Contributions to the mathematical biophysics of organic form. III. The formation of shell-shaped cellular aggregates, by N. Rashevsky; On the formal theory of nerve conduction, by Alvin M. Weinberg; A note on the horopter, by Alston S. Householder; A general fluid circuit theory of active chloride absorption, by H. C. Peters.

MATHEMATICS IN BACTERIOLOGY.

By Otto Rahn. Burgess Publishing Co., Minneapolis. $1.75. 10¾ x 8¼; iii + 63; 1939.

It is the object of this booklet to help the student to acquire an understanding of the quantitative interrelationships of the various life functions of bacteria by solving problems. Subjects under discussion include: unrestricted and restricted cell division and fermentation, growth of individual organisms, disinfection, statistics in bacteriology, and the use of graphs. Ample material has been provided for a class of students to practice formulas and equations. A sharp line is drawn between the terms growth and multiplication, since the author feels that the two are definitely different things.

PSYCHOLOGY AND BEHAVIOR

DANGEROUS THOUGHTS.

By Lancelot Hogben. W. W. Norton and Company, New York. $2.75. 8½ x 5¾; 283; 1940.

Hogben has brought together in this volume a series of essays dealing with his beliefs and theories on a variety of subjects related to social behavior. The title of the book derives from the author's realization that in times such as these it is dangerous not to be a partisan of either the Right or the Left in matters of political

idealogies. Of the fifteen essays that constitute this book, eight deal with problems of how to popularize science particularly so that the biological principles of human behavior may be better understood. Four essays are concerned respectively with comments on John Wilkins, William Petty, Havelock Ellis, and an assorted group of Scotch natural scientists. In the remaining three the author expounds again his views on social problems. An epilogue written after September 1, 1939 closes the book. "At last," he points out, "we have got the war against Hitlerism, the war for which the Labour Party has been clamouring during five years of frustration and the extinction of any vigorous constructive policy of domestic reform." This well expresses his judgment on the rôle played by the English Labor party to bring about the present European war. He concludes with the hope that the "Left intellectuals" will now abjure their errors, reenter the fold of democracy and help in the fight for the preservation of intellectual freedom. In this and all of the essays we are made aware of the author's command of language and of his wit and also of the internal conflict faced by the humanitarian biologist who seeks to apply his science to the study of human social phenomena.

WE CALL IT HUMAN NATURE.

By Paul Grabbe. Worked out in Cooperation with Gardner Murphy. Harper and Bros., New York and London. $2.50. 9¼ x 7½; [8] + 120; 1939.

The author of this interesting volume has hit upon something new in the field of presentation of scientific material. His ingenious and novel graphic methods of discussing the fundamentals of psychology have been found by well-known psychologists to be completely sound, as well as revolutionary—so much so that one of the leading psychologists of the day, Gardner Murphy, has participated in the preparation of the text, and has written a beginning note on "How this book came to be written."

The factual material is authentic and well documented, with a note of careful differentiation between what is established fact, and what is theory. The abundance of illustrative material, and the clear presentation of data in simple, everyday language, make the book not only readable, but intensely interesting to the lay as well as to the professional reader.

The master theme, which is neatly interwoven throughout the entire thesis, is that of the necessity of the individual, if he wants to live anything like a contented and sane life, to achieve some measure of harmony with his environment. In studying and conquering the physical world, the author believes that we have neglected the study of our social world. A note of doom is sounded for our civilization unless we are able to fathom predatory and anti-social man to the extent of reaching a basis for good-will, cooperation, mutual understanding and mutual respect.

THE PSYCHOLOGY OF EXCEPTIONAL CHILDREN.

By Karl C. Garrison. The Ronald Press Co., New York. $3.25. 8 x 5½; xiii + 351; 1940.

This book by the professor of psychology at North Carolina State College, is designed primarily for principals, teachers, and parents on whom the responsibility for guiding the development of exceptional children rests. Three general groups of exceptional children are considered: the gifted, the retarded and the physically handicapped. This last group includes children with defective vision, hearing or speech, children of lowered vitality, and left-handed and crippled children. The orientation of the book is against educating all children in a mechanical manner, against focusing attention exclusively on those factors in a given child which makes him exceptional, and towards the viewpoint that the personality of each child, regardless of what variation from average he may present, functions as a whole in his continual drive to maintain a satisfactory relationship to his environment. His education, therefore, should be adapted to his in-

dividual capacity and needs. The material presented is up to date and the book should prove of value as an introduction to the subject matter. There are four appendices, and author and subject indices.

THE INTER-RELATIONSHIP OF MIND AND BODY. *The Proceedings of the Association, New York, December 27th and 28th, 1938.*

By the Association for Research in Nervous and Mental Disease. Editorial Board: Foster Kennedy, Angus M. Frantz and Clarence C. Hare. Williams & Wilkins Co., Baltimore. $6.00. 9 x 6; xx + 381; 1939.

This is a testimonial volume in memory of Dr. Frederick Tilney. It is a report of a symposium in which twenty-two authorities in various fields of nervous and mental pathology participated, and the discussion that ensued upon the presentation of each contribution. None of the participants except Foster Kennedy has adhered at all closely to the subject of the symposium as announced in the prospectus, and which also serves as the title to the present work. The result is a collection of highly technical essays on various phases of abnormal mental states and the conditions that produce them, instead of an integration of dualistic philosophy such as the title would lead one to suspect.

There is an extensive but not exhaustive bibliography at the end of each chapter, and an index of ten pages at the end of the book.

A COMPARATIVE STUDY OF THE SYSTEMS OF LEWIN AND KOFFKA WITH SPECIAL REFERENCE TO MEMORY PHENOMENA.

By Sylvia H. MacColl. Duke University Press, Durham, N. C. $1.50. 9 x 6; vii + 160; 1939 (paper).

This study presents a polysyllabic comparative analysis and discussion of the psychological concepts and systematizations of Lewin and of Koffka, the latter selected as representative of the *Gestalt* point of view. The life-space of Lewin, based on a mechanical conception of nature, with emphasis on substance rather than function and tension as the "causal" reality is contrasted with the psychological field of Koffka which is based on functional relationships and organization. The various problems of memory are analyzed and the bearing of each of the two systems on these problems is considered. It is found that neither system deals completely with all memory phenomena.

The study is of academic rather than practical interest. It is thorough-going and scholarly, but would benefit by simplification in vocabulary and general presentation. A bibliography is included.

DELAYED REWARD IN DISCRIMINATION LEARNING BY CHIMPANZEES. *Comparative Psychology Monographs. Vol. 15, No. 5. Serial No. 77.*

By Austin H. Riesen. The Johns Hopkins Press, Baltimore. $1.00. 10 x 6¾; 54; 1940 (paper).

This monograph, from the Yale Laboratories of Primate Biology, presents a study of learning in chimpanzees when the reward for the correct discrimination of a stimulus is delayed to a point in time after the stimulus has terminated. Two control and three experimental animals were used. The method of investigation is described in detail and the results presented in detail and discussed. It is found that when reward is delayed more than a few seconds, visual discrimination learning is difficult or impossible, as compared with learning when the reward is immediate. This is a well-devised study and a sound contribution to the literature of animal behavior. There is a bibliography.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

THE PHILOSOPHY OF PHYSICAL SCIENCE. *Tarner Lectures 1938.*

By Sir Arthur Eddington. The Macmillan Co., New York; The University Press, Cambridge. $2.50. 8⅜ x 5½; ix + 230; 1939.

There are but few words that have suffered more from overwork and abuse than the term philosophy. To Eddington it means the generalizations derived from observations. The process by which generalizations are arrived at is epistemology. It is clear that while other defects may impair a philosophy whose epistemology is flawless, it is impossible to establish a sound philosophy upon an unsound epistemological base.

Eddington devotes more than half his book to a discussion of various phases of epistemology. Not until he feels that he has laid an unassailable foundation does he ask the question whose answer embodies the whole of his philosophy of physical science, "Is the bung-hole part of the barrel?" If the question be answered in the affirmative it appears that a barrel without a bung-hole is only part of a barrel. But a barrel without a bung-hole is greater than a barrel with one. Therefore the part is greater than the whole, and the first half of one of Euclid's axioms collapses like a flat tire. (The second half, that the whole is equal to the sum of its parts is retained by Eddington, but he makes it clear that the algebraic sum is referred to).

Now if to a bungless, and therefore incomplete barrel be added a bung-hole, that which is added is a negative quantity of wood. Euclid would have avoided the hypothecation of the negative quantity by answering that the bung-hole was not part of the barrel, which would be thoroughly consistent with a philosophy based on the observation of such tangible objects as barrels, rather than on the subatomic particles of modern quantum physics. But we know today that atoms are constructed of electrons and various other kinds of trons which when added together frequently neutralize each other. Therefore, some of these particles must have negative mass, but none have it absolutely. Negativeness is a matter of relativity. And neither did Euclid understand the relativity theory.

From this beginning Eddington goes on to draw some conclusions that seem highly esoteric, such that the number of chemical elements in the universe is equal to the number of dimensions, and that the number of particles in the physical universe is equal to the number of elements doubled 257 times. The result of this computation he sets out, and it is quite remarkable, but not more so than the man who figured it.

The present work is of much greater significance than the author's earlier one in which he discusses the relation between mysticism and science but it is not likely to have so many readers, as the thought is too profound for the average man to grasp.

THE PHILOSOPHY OF POWER: *First Principles. By Donald Murray. Williams and Norgate, London.* 12s. 6d. net. 8½ x 5½; 336; 1939.

The Philosophy of Power is built on the first and second laws of thermodynamics, being and becoming, growth and decay, and the belief that we live in a "Dualistic Diverse, and not in a Monistic Universe." The author considers himself "one of the great seers in direct line of apostolic succession from Kant and Spencer," Kant being the first of the great Actualist Philosophers, Spencer the second, and himself the third. *The Philosophy of Power* is based on Spencer's doctrines and the author's aim is to modernize Spencer—"to dot his 'i's' and cross his 't's' and translate his words into the modern thermodynamical phraseology." However, this work is almost entirely devoted, as the Spencerian philosophy is not, to problems of human welfare and the application of the two great generalized laws of thermodynamics, pressure energy and velocity energy, to such problems.

The author endeavors to debunk mathematics and those of its exponents who are trying to solve the riddle of existence by converting the universe into a mathematical proposition. He contends that this, the probability law, raises "the question of God versus Chance, . . .and Chance is denial of the existence of the thing called God." The author feels that this belief in the existence of God is "the fundamental basis for the well-being of men."

COMPOUNDING IN THE ENGLISH LANGUAGE. *A Comparative Review of Variant Authorities With a Rational System for General Use and A Comprehensive Alphabetic List of Compound Words.*

By Alice M. Ball. H. W. Wilson Co., New York. $2.50. 9½ x 6¾; x + 226; 1939.

Those who are in any way concerned with the writing or the editing of manuscripts are constantly puzzled and disturbed by the inconsistencies in the rules for the compounding of words which are set forth by various dictionaries and manuals. Miss Ball, as lecturer on editing and as co-author of the Style Manual of the Department of State, has made the study of compounding her particular field and has now put forth a guide destined to have an important place on the reference shelves of all working libraries.

The first part is taken up with a discussion of the general principles embodied in the various American and English dictionaries and style manuals. This part is planned chiefly to show the chaotic condition which has existed in the compounding of words, and the need for logical and simple rules to clarify the situation. This is followed by a section on a rational system of compounding, that is the most important part of the book, for here are presented the rules and principles, with explanatory remarks and examples, which have so long been needed. Unfortunately most of us will tend to neglect this part and consult the section which follows—Alphabetical list of compound words (something over 100 pages long)—which tells at a glance the proper form to use. A list of authorities cited and an index complete this useful volume.

SCIENCE AND EVERYDAY LIFE.

By J. B. S. Haldane. Lawrence and Wishart, London; The Macmillan Co., New York. 5s. net in England; $2.00 in America. 7¼ x 4¾; 284; 1939.

Haldane is of the firm belief that much scientific knowledge is without practical application because it is not made available to the lay reader. This collection of 70 articles represents the first 16 months' output of weekly articles (published in *The Daily Worker of London*) on science for popular consumption. In each article, the author, in his own words, ". . .attempted to do two things. I have tried to give a few facts which are not yet to be found in textbooks, and which a student leaving a university with an honours degree would not be expected to know. And I have tried to bring these facts into relation with everyday life." Anyone acquainted with Haldane's previous writings will fully realize his complete adequacy in achieving these two aims. Though much of the material is drawn from British sources, the underlying themes will find application in the lives of people from every country of the world. The material is presented clearly, simply, and in a very "human side of science" fashion.

SCIENCE FOR THE WORLD OF TOMORROW.

By Gerald Wendt. W. W. Norton and Co., New York. $2.75. 8 x 5⅜; 316 + 39 plates; 1939.

This is a commentary on those elements in the life of today that are to build the world of tomorrow. The turmoil of politics and the confused emotion of persons and peoples are absent—their place in the headlines is not their place in history. Wendt believes that man's outstanding achievement has been in the use of his intelligence to improve the environment of human life. He further feels that this in itself is *science*. Thus defined, science is a major social force, and we may evaluate our civilization by examining the rôle of science in it. This he proceeds to do. He discusses life in the age of science, sources of wealth and power, transportation, communication, the home and its importance, food, medicine and health, necessary luxuries, the use of leisure, and finally the scientific attitude. The book is beautifully illustrated with many views of the New York World's Fair and others chosen for their special appropriateness. An index is provided.

A History of Science in Canada.
Edited by H. M. Tory. The Ryerson Press, Toronto. $2.50. 9¼ x 6⅛; vi + 152; 1939.

At the 1938 meeting of the American Association for the Advancement of Science at Ottawa, nine men contributed papers on the rise and development of the major fields of pure science in Canadian laboratories. These papers, now collected in book form, indicate how substantial and significant Canadian research has been and is. Samuel Beatty outlined the progress of mathematics, A. Norman Shaw the advance of physics, W. E. Harper the history of astronomy. Frank Dawson Adams dealt with Canadian geology, W. Lash Miller with the beginnings of chemistry, Frère Marie-Victorin with botany, and F. R. Dymond with zoology. Both Leo E. Parisean and J. J. Heagerty spoke for Canadian medicine. Finally an introduction has been contributed by H. M. Tory, director until recently of the National Research Laboratories.

The Frame of the Ancient Greek Maps: *With a Discussion of the Discovery of the Sphericity of the Earth. American Geographical Society, Research Series No. 20.*
By William A. Heidel. American Geographical Society, Broadway at 156th St., New York. $2.50. 8 x 5⅛; x + 141; 1937.

No Greek maps have come down to us. We know that they had maps and a few descriptions in contemporary literature, such as Homer's oft-quoted statement that the river Oceanus flows round the world, are our only source of knowledge of what these maps must have been like. Aristotle's description of the torrid, temperate, and frigid zones has no bearing on the matter, for he derived them from mathematical rather than from cartographical considerations.

The author has gone over the literature with a fine tooth comb, and assembled everything that throws any light on the matter. The book is, of course, highly technical but lucidly written, and is an interesting treatise on a matter that occupies but a small place in modern thought.

Science in Your Life.
By John Pfeiffer. Illustrated by Ludwig Mactarian. The Macmillan Co., New York. 60 cents. 7⅜ x 5; [6] + 109; 1939.

This little book is a brief story of the many wonders we have learned to accept unquestioningly in our modern living. Working up from the early Egyptians and Galileo, the author, science editor of *Newsweek*, carries us step by step to the radio in the living room, the electric refrigerator in the kitchen, the wireless and the telescope and to the many other mysterious conveniences of the modern age. He touches briefly on the science of modern warfare, which has increased the power to kill, but he ends on an optimistic note, ". . .this power need not be used in the future," he says, "only three centuries separate Galileo and television. And there are still millions of years to go."

Modern Methods and Materials for Teaching Science.
By Elwood D. Heiss, Ellsworth S. Obourn and C. Wesley Hoffman. The Macmillan Co., New York. $2.50. 8½ x 5⅝; x + 351; 1940.

The principles set forth in this book are most applicable to primary and secondary school teaching. The first section presents an analysis of the various methods of teaching science. It discusses lectures, text books, laboratories, demonstrations, and reading. The final section lists the sources from which flat pictures, models, charts and posters, films, books, and periodicals may be obtained. An excellent aid to the beginning teacher in the organization of his courses.

What You Want to Know about Developers: *Fine Grain and Otherwise.*
By Edmund W. Lowe. Camera Craft Publishing Co., San Francisco. $2.50. 7¾ x 5½; 175; 1939.

Physics in 1939.
By Thomas H. Osgood. Reprinted from Journal of Applied Physics, Vol. 11, No. 1, pp. 1–17, 1940.